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Comet Hale-Bopp on the Move

The Quest for Dark Matter

- Kodak's Hot New Astrophoto Film
- ASTRONOMY Reviews Celestron's Starhopper

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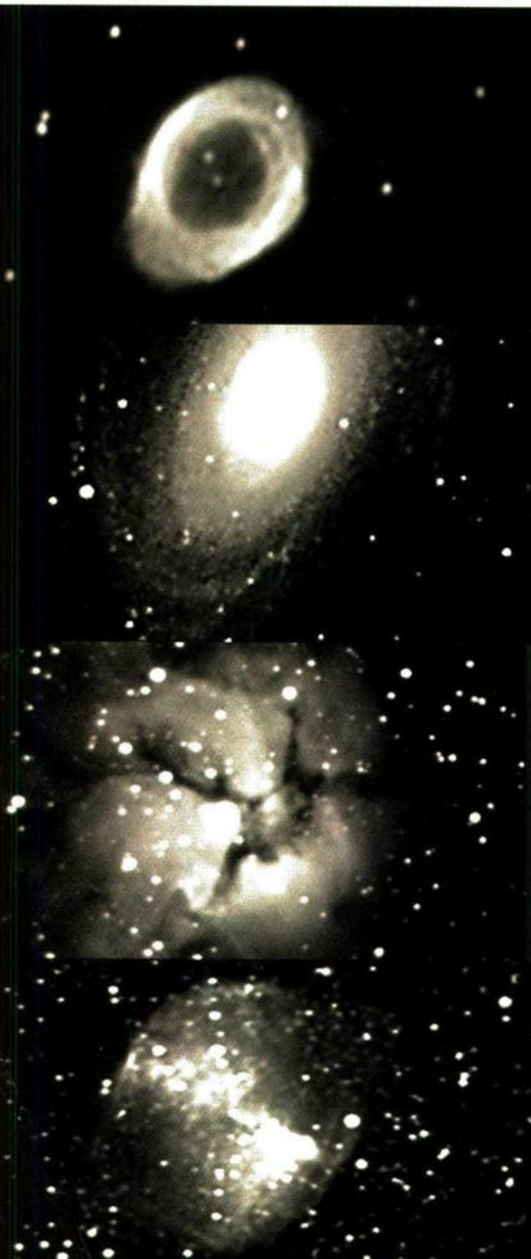
Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot; Dumbbell Nebula (M27), 12" LX200, John Hoot.



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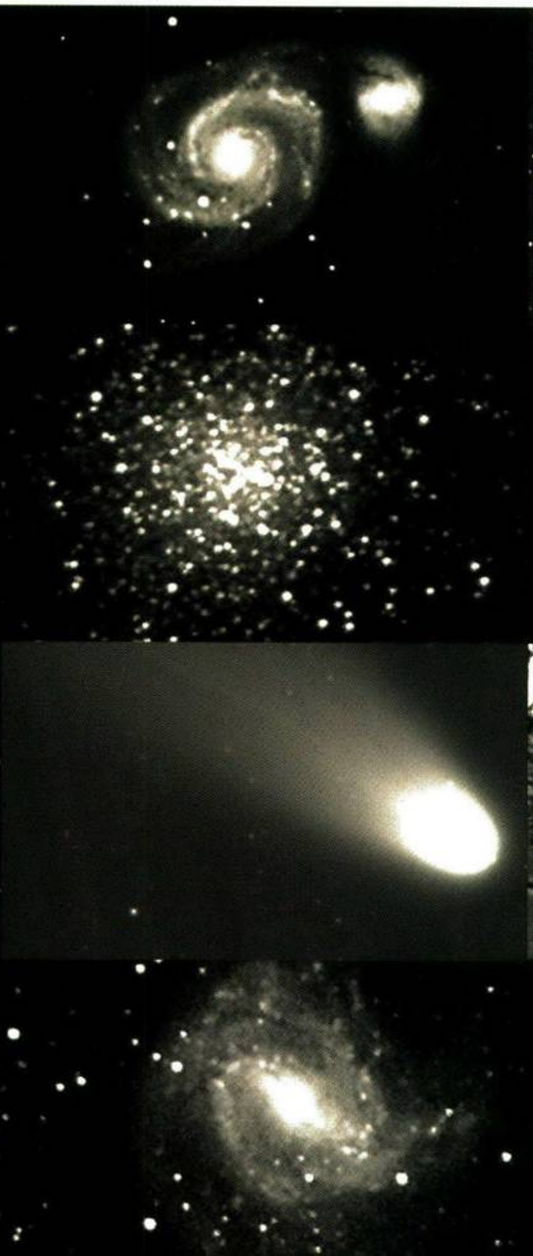
Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Comet Hyakutake, 8" LX200 with f/6.3 Focal Reducer, John Hoot; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



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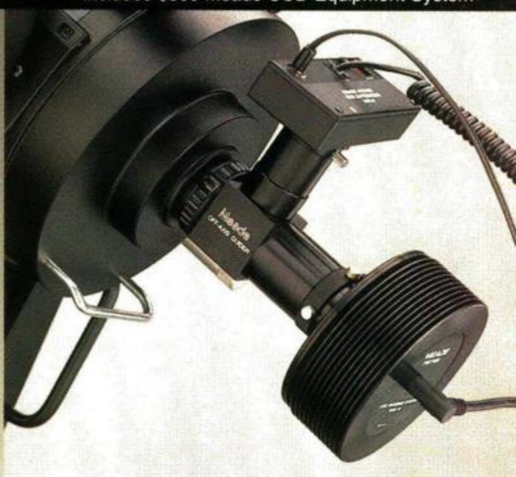
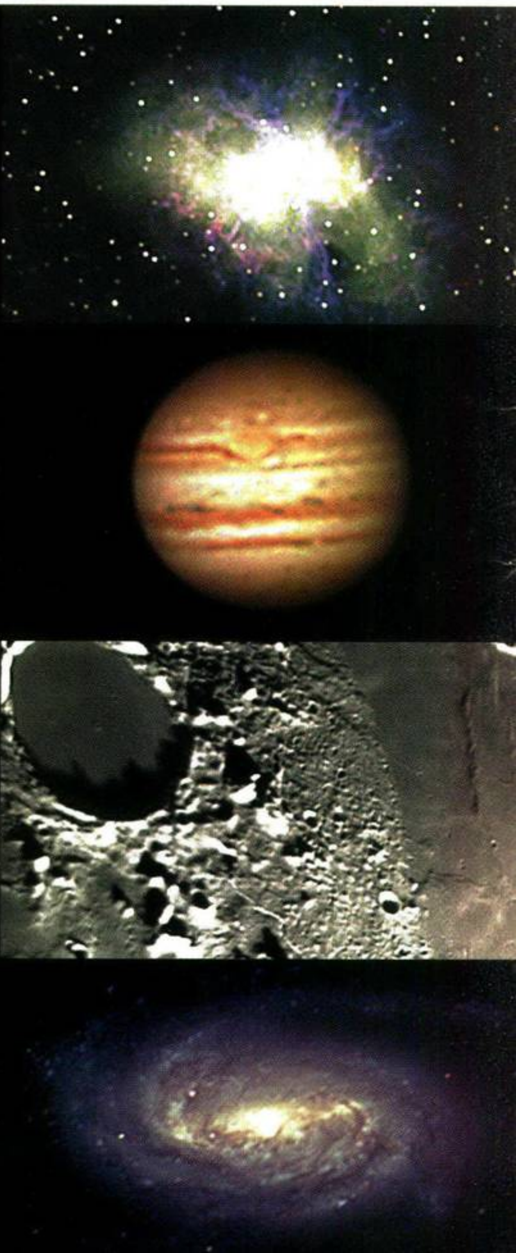


Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker; NGC 2903, 25" reflector, Jack Newton.



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Specifications: Includes autoguider/imager body (4" dia.) with digital readout of operating data and with Texas Instruments TC-255 CCD chip (3.30 x 2.40mm; 336 x 242 pixels; pixel size: 10µm - square); 8-bit A/D conversion for 256 gray-levels in the image; 1.25" barrel for standard eyepiece-holders; cords for connection to telescope and PC. Software features: image transfer and display; contrast control; smoothing/sharpening filters; automatic and manual exposure levels; automatic dark-field exposure and flat-field sequence; pixel binning. Operating manual. **$495.** (+ $20 packing and shipping in 48 states)

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Specifications—Includes autoguider/imager body (4" dia.) with digital readout of operating data and with Texas Instruments TC-255 CCD chip (3.30 x 2.40mm; 336 x 242 pixels; pixel size: 10µm - square); 16-bit A/D conversion for 65,536 gray-levels; 1.25" barrel for standard eyepiece-holders; cords for connection to telescope and PC. Software features: same as for Pictor 208XT *(above)*, and with software provision for attachment to Pictor 616 Color Filter System. Operating manual. **$695.** (+$25 P & S)

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Pictor 416XT imagers are shipped at no additional charge with the $800 Meade CCD Equipment System.

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Astronomers have slowly come to realize that they can't account for most of the universe's contents. What could this dark matter be? *Marcia Bartusiak.*

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The edge-on spiral galaxy NGC 4565 in Coma Berenices. Courtesy NOAO.

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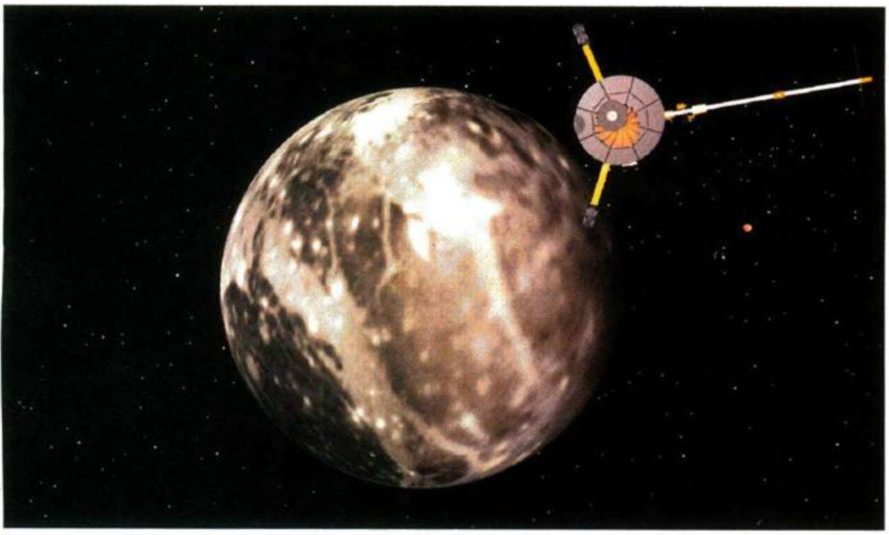
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BEHIND THE SCENES

Imagine the Universe

Since its inception in 1973, ASTRONOMY has featured the hypervision of astronomy artists in its pages. Paging through two decades' worth of back issues, it's clear to see that ASTRONOMY wouldn't have been the same publication without the talents of artists like Michael Carroll, Ron Miller, Jim Hervat, Mark Paternostro, Adolf Schaller, and countless others. More recently, the provocative works of Julian Baum, Lynette Cook, and Bob Eggleton have graced our pages. In fact, in this issue, we feature no less than four commissioned pieces by Lynette Cook on the subject of dark matter (beginning on page 34).

So when Mark Paternostro of the Adler Planetarium and Astronomy Museum in Chicago asked our help in loaning selections from ASTRONOMY's space art collection to the Adler for a special exhibit, we readily agreed. The exhibit, called "Imagine the Universe," opened July 20 to an enthusiastic reception (it closes October 20). Works from eight internationally recognized artists transported visitors from lunar craters and the icy moons of Saturn to the heart of quasars and a ringside seat at a galaxy collision. Each painting manifested abundant imagination, to be sure, but unlike science-fiction art, space art is grounded in science fact. As alien as the landscapes appear, you can't dismiss the perspective as totally unreal or fanciful.

A real treat of the exhibit was a collection of rarely viewed works by the pioneering space artist Chesley Bonestell. Included were his stunning paintings of Saturn, published in a 1944 *Life*, as well as his depictions of space flight that appeared in *Collier's* in the 1950s. Some of these works were images from my childhood (from books like *The Exploration of Mars* by Willy Ley and Wernher von Braun). It was paintings like these that presaged many of the triumphs of space exploration in the 1960s and 70s (though, admittedly, real rockets never had the seductive aerodynamic appeal of Bonestell's).

"Imagine the Universe" also featured examples of what might be called ancient space art. Elaborate celestial charts from the likes of Johann Bode's *Uranographia* (1801), van Luchtenberg's *Quadrans Holometrius et Universalis* (1680), and Bayer's beautiful handcolored *Uranometria* (1661), depicted the night sky as a landscape endowed with myth and legend. In many ways, the illustrations embodied mankind's social and cultural imprint on the stars.

We celebrate the far-reaching vision of space artists, and look forward to continue bringing you their insightful views in the pages of ASTRONOMY. Together, we'll show you the universe.

Sincerely,

Jeff Kanipe

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LX10 Electric Declination Motor System	**85.**
#2014 Magellan I Telescope Computer System for LX10, with 12,218-object database	**375.**

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10"
7"
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LX50 models shown with optional Field Tripod.

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■ **Rigid, Durable, Beautiful Dobsonian Mountings**, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the location and tracking of celestial objects.

■ **Optical Tubes:** Starfinder Dobsonians include the same strong, spiral-wound optical tubes used on Starfinder Equatorials *(right).* All telescopes include a multi-coated MA25mm eyepiece; each tube is factory pre-drilled for the optional 6 x 30mm or 8 x 50mm viewfinder.

■ **Performance!** A Meade Starfinder Dobsonian or Equatorial opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects—nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space photography.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$39; 8"–$49; 10"–$69; 12.5"–$79. 16"–$45 packing, shipped truck freight collect.

ACCESSORY OFFER!

At the time you order any Meade Dobsonian, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, *and* the Meade #637 6 x 30mm viewfinder with metal bracket for a **total of $49.95!** *Purchased separately, the 2 eyepieces and viewfinder sell for $125.85!* Offer valid until further notice.

AUTHORIZED U.S. MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Illinois & Info.: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

STARF
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Immediate delivery!

Computerize your Meade® Starfinder Telescope for only $295!

Spend your time **observing, not searching** for objects! **With the incredible Meade Magellan™ Telescope Computer System** attached to your Meade Starfinder Dobsonian or Equatorial, finding any of **12,218 celestial objects** is almost as easy as pointing the telescope.

■ Don't spend $400, $500, or $600 for a computer system with fewer features! Designed and manufactured at the Meade Irvine facility, the Magellan I includes one of the largest object databases available, incorporates only premium-grade components, and sells for a low $295!

MEADE
ENTER
MODE
PREV
NEXT
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM
U.S.A.

Actual Size: 4" x 5" x 1.25"

■ **Easy to Use!** Just input the R.A. and Dec. of the object you wish to observe, or call up an object from Magellan's massive database. Magellan allows you to slew the telescope manually to the object and place it in the visual field, quickly and precisely.

■ **Fast 2-Star Alignment:** Point the telescope at 2 bright stars selected from the star database, and the computer is aligned in *seconds.* No need to input time or date, latitude or longitude. Magellan's powerful microprocessor calculates telescope position in milliseconds and directs your movements of the telescope for fast, accurate object location.

Meade Magellan II Computer-Corrector for Starfinder Equatorials

Plug the Magellan II into the control panel of your Meade DC-powered Starfinder Equatorial *(right)* and you have *all the capabilities of the Magellan I (above)* ***plus*** a 4-speed, dual-axis, drive-corrector/microslewing system!

Includes: Magellan II hand controller *(right)* with 4 dual-axis speed rates (2x, 8x, 16x, 32x sidereal); high-resolution 4096-pulse encoders for both axes; electric Declination control system; 12,218-object computer database; 2-star alignment; RS-232 serial interface. (For Meade *DC-powered* Starfinder Equatorials, only.)

#2018: for Starfinder Equatorial 6", 8", or 10" . . . . $495.
#2019: for Starfinder Equatorial 16" . . . 595.

Prices plus $20 packing & shipping in the 48 states.

INDER
UTERS

■ **High-Resolution 4096-pulse Encoders:** Each Magellan system includes two premium-grade, high-resolution encoders. Encoder precision is 5.3 arc minutes.

■ **Large 32-Character LCD Red-Backlighted Display:** The same LCD display included with the Meade LX200 hand controller. Includes variable illumination from dim to bright.

■ **12,218-Object Database:** A database that includes an amazing array of objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

■ **Supplied Complete!** With other computers you pay *once* for the basic controller and then pay *again* for the "Encoder Installation Package." Meade Magellan Systems are supplied **complete** with: controller/display unit (4" x 5" x 1.25"); encoders for both telescope axes; RS-232 serial interface; bracket for convenient placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan is ready to use. First-time installation is quick and simple.

Meade Magellan I Telescope Computer Systems

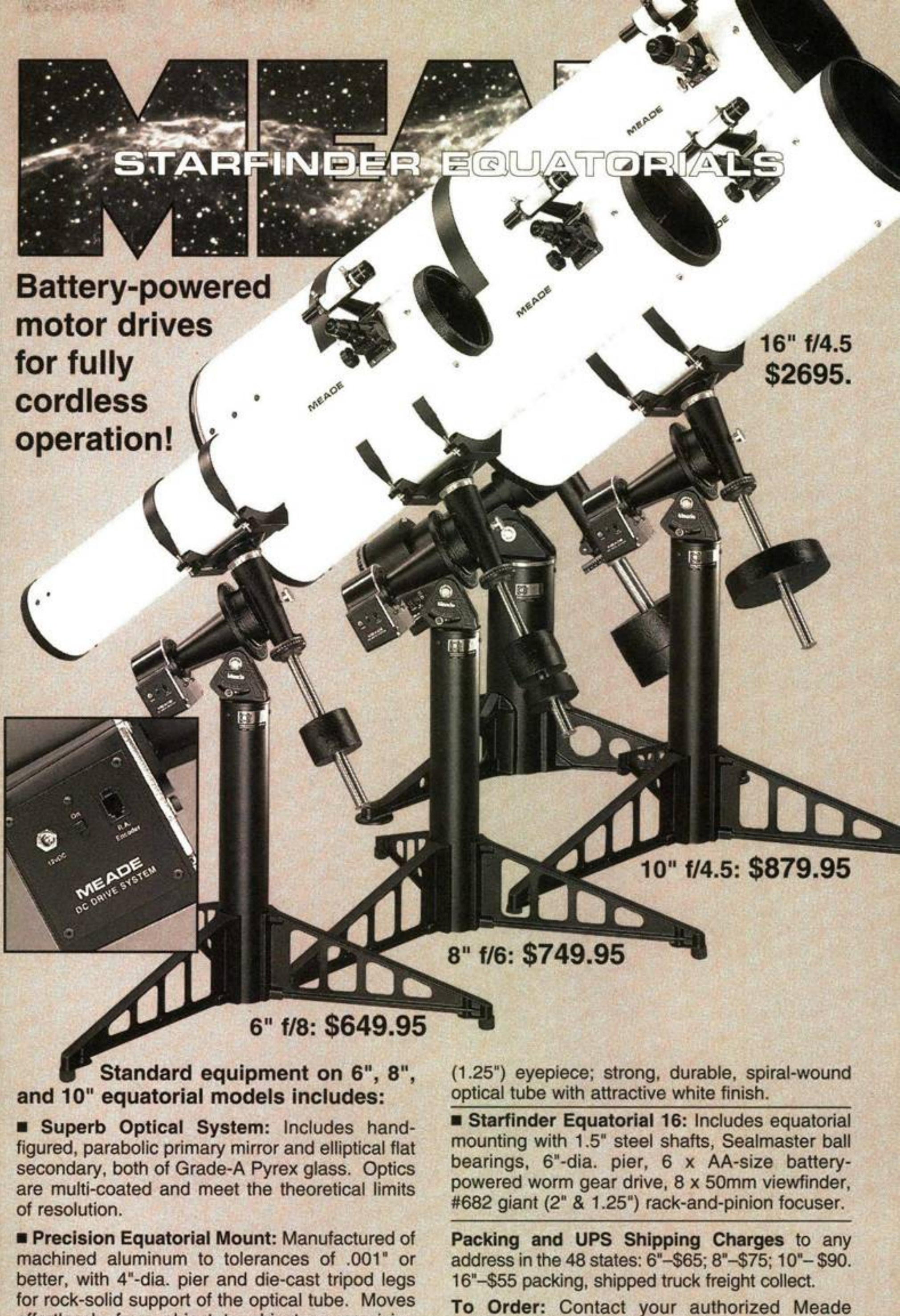
#2010:	**for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16"**	**$295.**
#2011:	**for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10"**	**295.**
#2012:	**for Meade (DC-powered) Starfinder Equatorial 16**	**295.**

All prices plus $15 packing & shipping in the 48 states. Prices shown are suggested U.S. national mail-order retail prices. For additional information on Meade Magellan systems, send for your free copy of the 94-page **Meade 1996 General Catalog.**

MEADE
MAGELLAN II
COMPUTER - CORRECTOR
ENTER
MODE
FIND
N
E
W
S
M 9
32X 7
8
STAR 6
16X 4
5
CNGC 3
8X 1
2
PREV
NEXT
2X 0
U.S.A.

MEA
STARFINDER EQUATORIALS

Battery-powered motor drives for fully cordless operation!



16" f/4.5 $2695.

10" f/4.5: $879.95

8" f/6: $749.95

6" f/8: $649.95

Standard equipment on 6", 8", and 10" equatorial models includes:

■ **Superb Optical System:** Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

■ **Precision Equatorial Mount:** Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

■ **Battery-Powered Cordless Drive System!** Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries inserted through the drive cover. Control panel *(see inset photo, above)* also permits powering of telescope from 12v. auto cigarette lighter plug, using optional 25' cord.

■ **Accessories and Components:** Rack-and-pinion focuser (1.25") with 2.6" travel; #637 6 x 30mm viewfinder; multi-coated MA25mm (1.25") eyepiece; strong, durable, spiral-wound optical tube with attractive white finish.

■ **Starfinder Equatorial 16:** Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6"-dia. pier, 6 x AA-size battery-powered worm gear drive, 8 x 50mm viewfinder, #682 giant (2" & 1.25") rack-and-pinion focuser.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$65; 8"–$75; 10"– $90. 16"–$55 packing, shipped truck freight collect.

To Order: Contact your authorized Meade Advanced Products Dealer. All prices shown are suggested USA mail-order retail prices.

Free 94-page Meade 1996 General Catalog is available from your authorized Meade dealer or directly from Meade Instruments.

ACCESSORY OFFER!

At the time you order any Meade Starfinder Equatorial Telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, for a **total of $29.95!** *Purchased separately, the 2 eyepieces sell for $75.90!* Offer valid until further notice.

ADVANCED PRODUCTS DIVISION

Meade Instruments Corporation

World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur

16542 Millikan Avenue, Irvine, Calif. 92714 □ (714) 756-2291
FAX: (714) 756-1450

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MEADE SUPER PLÖSSL
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MEADE
MEADE

MEADE ETX

90mm Maksutov-Cassegrain

Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope— Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$495***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$495*, *complete!*

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

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16542 Millikan Avenue, Irvine, Calif. 92714
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MEADE EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

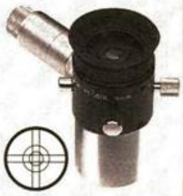
6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 3000™ Plössls 50° field; multi-coated

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any *telescope accepting 1.25" eyepieces, even those with* limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

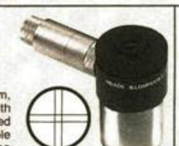
$42.95 (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

HOW TO ORDER

- Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Info/IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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ASTRO LETTERS

Shedding New Light on Pumpkin Carving

This is our first attempt at carving "Astro-pumpkins," but they received neighborhood rave reviews. Next year we'll try something more challenging, like a quasar, a black hole, or some dark matter! — *Victor and Avalon Rogus, Des Plaines, Illinois*

Victor and Avalon Rogus

The Great Pumpkin has nothing on these creative designs. Left to right: Comet Halley, the Moon, and the Sun.

Setting the Record Straight

Alister Ling mistakenly wrote that NGC 6888 in Cygnus is a supernova remnant (Sky Almanac, January 1996). In fact, it is an emission nebula associated with a Wolf-Rayet star, SAO 69592, which has a spectral class of WN6. No pulsar or prominent radio source lies at this location. Although it might one day become a supernova, at present SAO 69592 is alive and kicking. — *David Knisely, Beatrice, Nebraska, dk84538@ltec.net*

Space Exploration Could Benefit Mankind

It was interesting and encouraging to learn that space exploration is still alive ("Journey to the Outer Limits," August 1996). Space exploration could advance if the scientific community would embrace space projects that would benefit mankind rather than just the scientists interested in space exploration.

If astronauts mined a nearby asteroid, for example, the metals and minerals gained would lessen the expense of further space exploration, and provide cheaper raw materials to produce goods and services such as computers, cars, building materials, and medicines. — *Matthew Raffel, Cumming, Georgia, isoftdev@mindspring.com*

Did Our Ancestors Practice Bad Astronomy?

"Astronomy's Strange Trip" (June 1996) is too simplistic a treatment of the history of astronomy. If our own enlightenment has taught us anything, it's that ancient scientists must be viewed in the context of their times and not in ours. — *Richard J. Wilders, North Central College, Naperville, Illinois, rjw@noctrl.edu*

Ptolemy's *Almagest* does not mention "crystalline spheres," and only refers to spheres in reference to other astronomers. Instead, he used circles as mathematical instruments to make calculations and predictions about astronomical observations. Circles were his mathematical tools of choice and were merely methods of calculation. That Ptolemy found such a tool useful seems like very good science. — *John S. Steadman, St. John's College, Santa Fe, New Mexico*

Credit Where It's Due

I enjoyed the review of the Starsplitter Compact (May 1996). While it is an excellent telescope at a competitive price, it is not an original design. I have been building an ultraportable twin-truss Dobsonian since 1991. In turn, my compact design draws upon the ideas of fellow amateur telescope makers Thane Bopp, Dick Suiter, Tom Burns, and Bob Bunge.

Starsplitter has adopted a public-domain design and produced its own version. Imitation may be the sincerest form of flattery, but an occasional acknowledgment of someone else's work would also be appropriate. — *Ronald L. Ravneberg, Columbus, Ohio, RRavneberg@aol.com, http://www.tiac.net/users/atm/ravne.html*

Thanks For a Great Magazine

Everything about the universe inspires and amazes me. I am a beginning astronomer and I find locating certain constellations and planets a challenge I love to take on. Reading ASTRONOMY and using the Southern Sky charts has helped me understand the cosmos. — *Denise Georges, Sydney, Australia*

Are We Alone?

The voting continues. In the July 1996 ASTRONOMY, Robert Naeye, associate editor, invited readers to vote "Yes, other civilizations exist in the Milky Way Galaxy," or "No, we are alone in the Milky Way Galaxy." As of press time, we have received about 1,200 votes and the ratio is 80 to 20 percent in favor of the existence of other civilizations.

Yes, There Are Others

Yes, other civilizations exist in our Galaxy, but they are too few and far between for our current technology to detect. We are only at the primitive beginnings of our technological age.

For instance, what makes an extraterrestrial civilization "civilized?" If it means that a society has to be detectable from several thousand light-years away, our available technology would be difficult to detect. I suppose this means that human beings, at a fundamental level, are completely uncivilized! — *James F. Shumaker, Kiev, Ukraine, SchumakerJ@KIEVWPOA.us-state.gov*

Every time I tried to shoot down Robert Naeye's hypothesis, he countered with a rook to queen move. He makes a good argument for the improbability of intelligent life. However, the undeniable fact remains that, at least once, life has overcome the odds and may do so again. Thank you for presenting such marvelous food for thought. — *Andrew G. Bacchi, Shaftsbury, Vermont, bacchia@cscacs.csc.vsc.edu*

No, We Are Alone

If you really think about all the things that must occur to bring about intelligent life, you begin to realize that it might be a rare occurrence. Look at complex life forms (like the human body) from a systems engineering point of view. Any engineer

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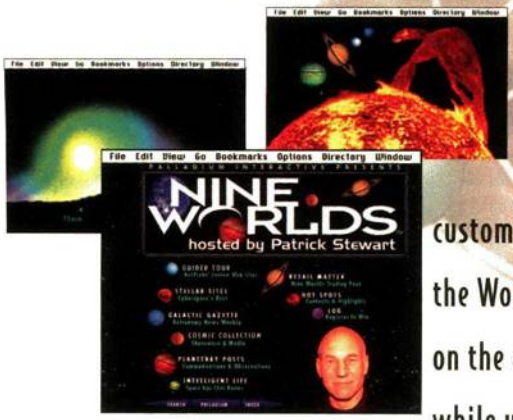

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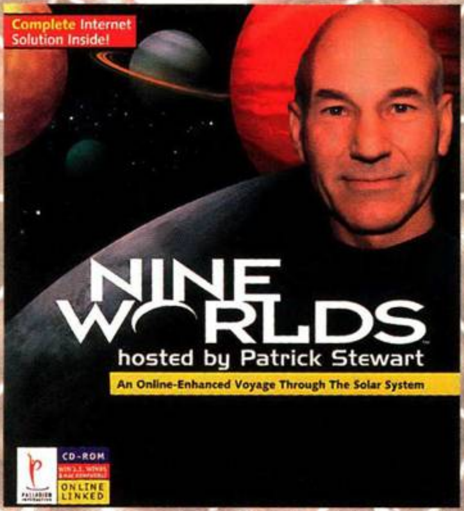
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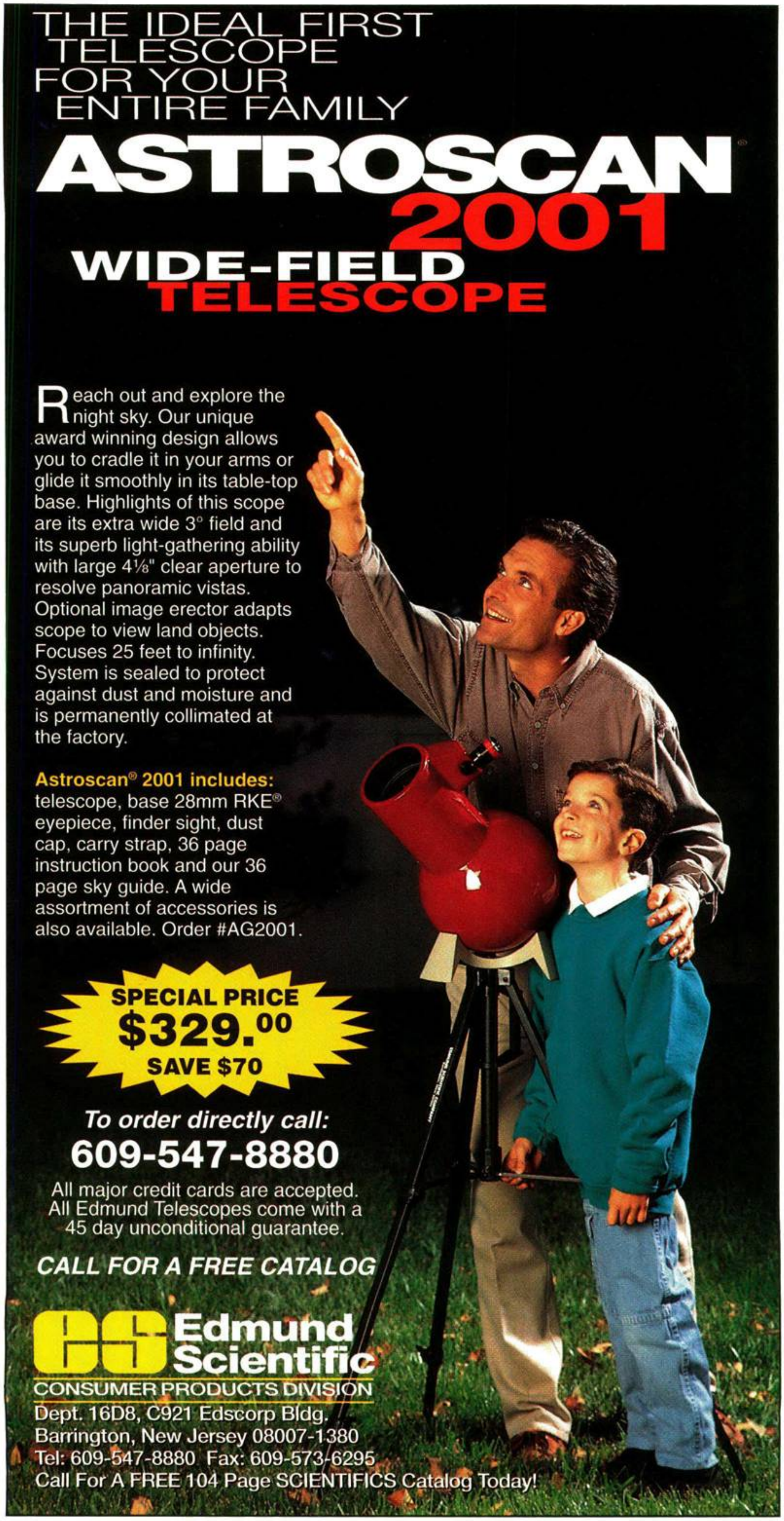

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will tell you that complex systems do not assemble or design themselves.

No one bothers to point out how difficult it is to go from a simple amino acid to the highly complex molecules that make up life. They also fail to point out how many things can go wrong along the way. Thanks for having the courage to publish an article that goes against the grain of popular opinion. — *Frank Rose, Irvine, California, 71763.176@compuserve.com*

I vote, reluctantly, no. I think we are the only human-class intelligent life in the Milky Way. As for the rest of the universe, who knows? I think life is quite common. It has proved tenacious and has adapted to nearly every environment on this planet. Because we don't know the mechanism by which it started, we can't know how often the necessary conditions might exist.

You say only the chordates have evolved intelligence. How about the cephalopods? They, at least, fit into that exclusive club. And anyone who has ever owned a parrot or one of the corvids will tell you they are intelligent. The phrase "bird-brain" might apply to chickens, but it is also a classic example of mammalian chauvinism. — *John Steele Gordon, North Salem, New York, JGordon669@aol.com*

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ASTRONOMY welcomes feedback. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187, or on the Internet, use letters@astronomy.com. Letters may be edited for length and clarity.

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Observing at the Edge

by Patti A. Kurtz

Star trails above the Grand Canyon from Yaki Point.

Unless noted, all photos by Astronomy: Patti Kurtz

"They come to the canyon from all over the world, expecting to be amazed, and we add to that by showing them the sky as they have never seen it before," says Dean Ketelsen of the Tucson Amateur Astronomy Association (TAAA).

He led an enthusiastic group of amateur astronomers in the star-packed, 6th annual Grand Canyon Star Party — a week-long delight for the public at the Grand Canyon in Arizona, June 8-15. The National Park Service cooperated with the TAAA to provide nightly thrills for anyone interested; one star party was held at Yavapai Point on the South Rim of the canyon, while yet another, organized by Karen and Deloy Pierce, perched on the North Rim at the Grand Canyon Lodge.

The North Rim partiers came from Utah, Alabama, Arizona, British Columbia and Ontario, Canada.

Venerable San Francisco Sidewalk Astronomers (SFSA) set up shop on the South Rim, along with volunteers out of clubs from all over North America. The two groups communicated with each other across the mile-deep abyss via CB radios. A couple folks from each group even made the six-hour, 211-mile drive around the canyon to visit the other side.

Famed telescope maker and SFSA founder, John Dobson, was in his element at the South Rim. He spent two days hiking below the rim, telling hikers he met on the trails about the star party and program above.

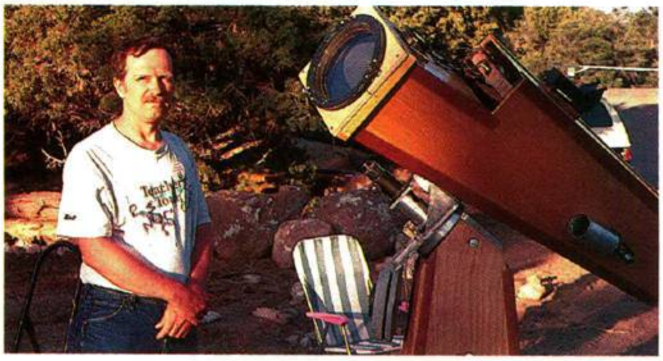
He also single-handedly figured a mirror and supervised the construction of a telescope that was built on-site and donated to the Grand Canyon School. This was an extraordinary daytime exhibit for the public and a valuable contribution to the children in the area, not to mention an unforgettable experience for many of the astronomers present.

Additionally, visitors were treated to daytime solar viewing and evening celestial slide shows along with terrestrial views of the canyon that were

Mike Spooner

An animated John Dobson discusses astronomy with Patti Kurtz before a slide show and public observing session at Yavapai Point.

Canyon in the round.



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second to none. Astronomers then invited them to stay and experience the stars through the telescopes.

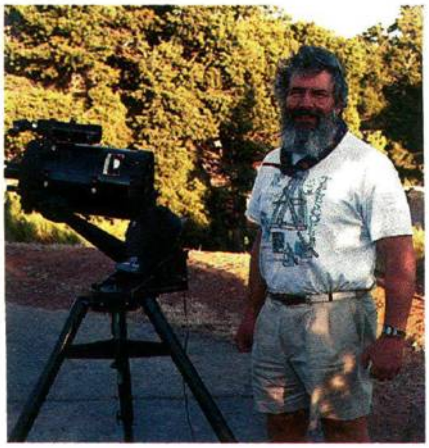
Park patrons observed many showpiece objects through the 70 plus telescopes, including Omega Centauri (NGC 5139), M51, M13, M104, Messier objects in Scorpius and Sagittarius, and Jupiter, which thrilled participants one night with a shadow transit of two Galilean moons. Hale-Bopp took center stage at the South rim, appearing naked-eye to skilled observers, and telescopically spectacular with its stellar inner coma and asymmetric outer coma.

By now you may be asking why 75 amateur astronomers would drag their families and telescopes, for what might be their only vacation of the year, to a week-long public viewing frenzy at the Grand Canyon.

For some, it was about teaching. For others it was about sharing a new and exciting opportunity — a first-hand experience of the universe in all its glory. Many of the park visitors had never looked through a telescope before. Most had no idea that galaxies, star clusters, and nebulae were within reach of a pair of binoculars or a reasonable aperture telescope.

"Fabulous!"; "A completely unexpected delight"; and "What a treat" were typical comments overheard.

One couple left their sleeping children to sneak a peak through the



Bob Goff of Tucson, Arizona, waits for nightfall and the canyon's dark skies, to share the universe with park visitors.

Inspiring tears and cheers, San Franciscan Barry Hirrell closes out the twilight talks to a crowd of nearly 200 at the South Rim.

telescopes. A few glances convinced them to return to camp and retrieve their older children for looks as well. The pajama-clad children then advised their parents to go and retrieve their younger siblings to share the night views. On the North Rim, a woman from Texas thanked the Pierces by saying, "I will not look at a star again without remembering you at the Grand Canyon and how you have changed my life."

John Dobson said, "You just never know when you'll make a difference in someone's life."

As I stood on the sidewalk next to a group of gazers, a 19-year-old former gang member from Chicago stepped back from an eyepiece. "I never thought I'd ever get to see the Grand Canyon and I've never looked through a telescope," he said. "Now look at me, I'm at the Grand Canyon and I'm looking through all these telescopes. Man, this is life. This is bigger than life."

Next year's Grand Canyon Star Party is tentatively set for June 7-14, 1997. Contact Dean Ketelsen, 1122 East Greenlee Pl., Tucson, AZ 85719, (520) 293-2855, ketelsen@as.arizona.edu. Make your reservations several months in advance. ☐

Patti Kurtz is ASTRONOMY*'s assistant editor. She advocates educating the public in all areas of science, particularly astronomy.*

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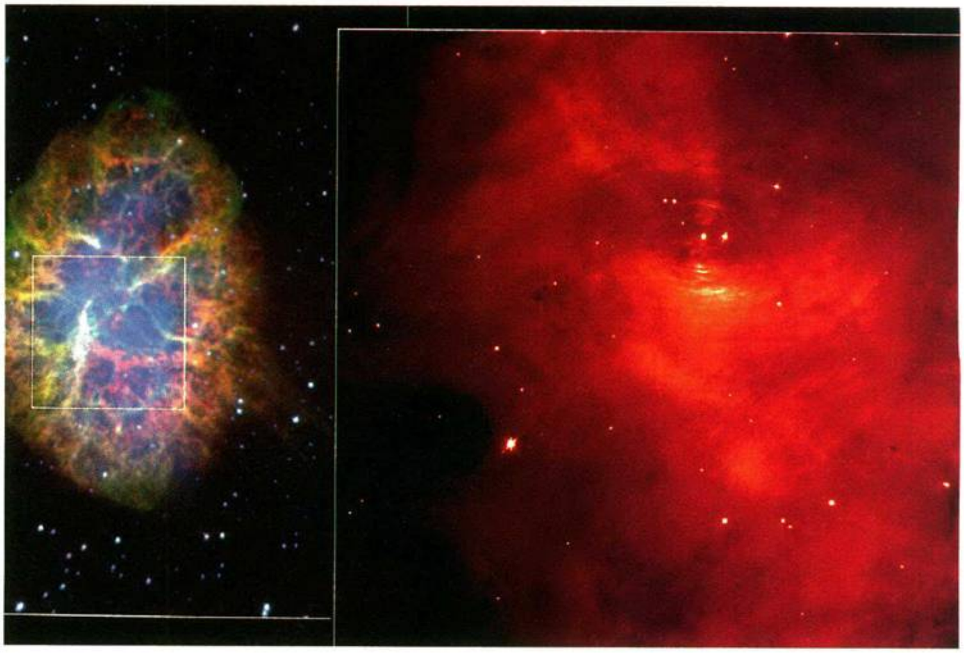
The Crab's Heart



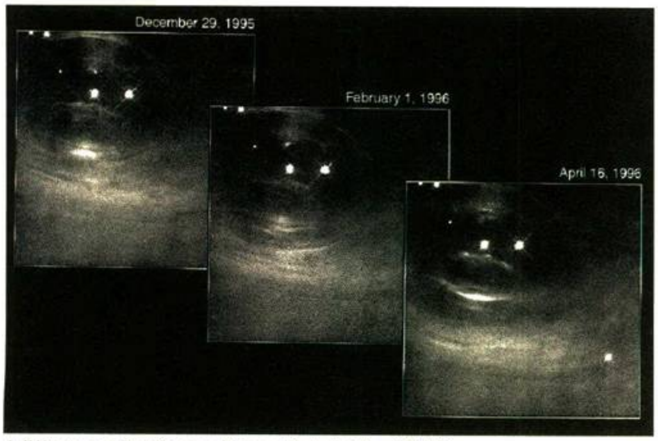
NASA/STScI and Palomar Mountain Observatory

The entire Crab Nebula, 7,000 light-years away in Taurus, appears in a Palomar Observatory photograph (left). The red, green, and yellow filaments are the tattered remains of the exploded star. The Hubble Space Telescope imaged the inner region of the Crab (right). The pulsar is the left of the two bright stars in the upper center.

The Hubble Space Telescope has peered deep into the heart of the Crab Nebula, the 10 light-year-wide remnant of the supernova witnessed by Chinese astronomers in 1054. Hubble took a series of images of the Crab's central regions over several months, revealing a much more active environment than anyone had previously imagined. "In astronomy, normally if you see something change over your career you get excited about it," says Jeff Hester of Arizona State University. "But the Crab Nebula is so dynamic that if you wait for longer than about a week to get your next look, you'll get the wrong impression because things have changed so terribly much."

The Hubble images reveal how the central star, a city-sized pulsar that is more massive than the Sun, causes the nebula to shine with the energy of 100,000 Suns. The pulsar, a remnant of the exploded star's core, rotates 30 times per second. The incredibly rapid rotation powers a wind of charged subatomic particles that streams away at half the speed of light. Most theories predicted that material would stream off the pulsar in all directions. Surprisingly, Hubble shows that the wind is concentrated along the pulsar's equatorial plane, creating light-year-long wispy features that look like waves rolling up on a beach.

In addition, the pulsar's rapid rotation and intense magnetic field drive two intense jets of particles that zoom away from the poles at near light speed. As one of the jets slams into the surrounding nebula, it generates a small, bright knot that comes and goes and moves around, leading astronomers to dub it the "dancing sprite."



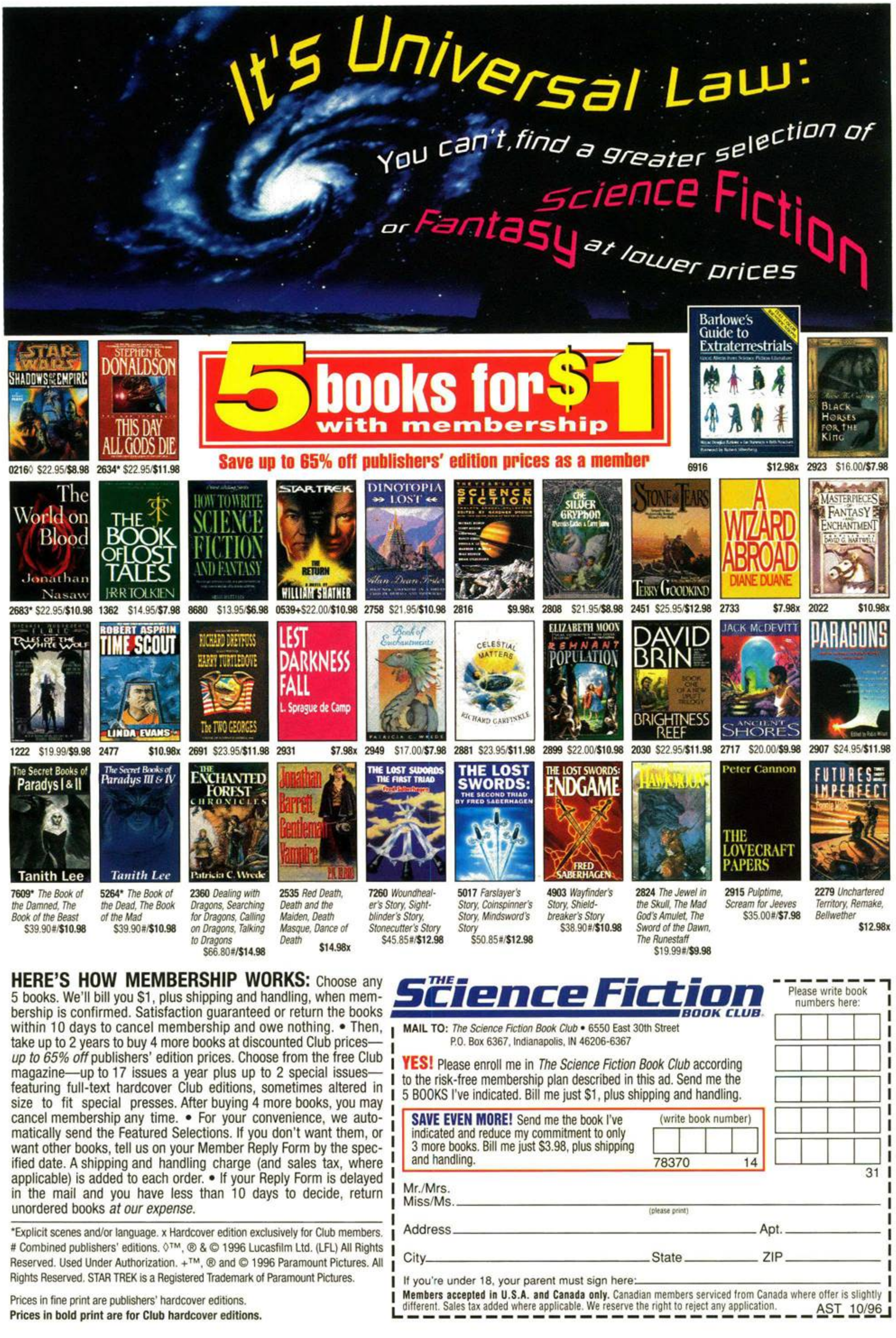
Jeff Hester and Paul Scowen (Arizona State Univ.) and NASA

Three Hubble images show changes in the inner Crab over 3½ months. The pulsar is the left of the two stars in the upper center. Surrounding the pulsar is its equatorial wind of charged particles, which appears as light-and-dark concentric circles that stream away at half the speed of light. Just above the pulsar is the "dancing sprite," which is created when a jet of particles emanating from the pulsar slams into the surrounding nebula.

If you're hooked up to the Web and have the ability to download mpeg files, check out three Crab Nebula movies at: http://www.stsci.edu/pubinfo/PR/96/22.html.

New Deep Space Camera

A new electronic camera developed by Gary Bernstein (University of Michigan), Tony Tyson (Bell Labs), and collaborators will allow astronomers to survey large tracts of deep space in a manner never before possible. The so-called Big Throughput Camera, or BTC, collects more light per second than any camera previously built. The BTC is also the first camera of its type that can effi-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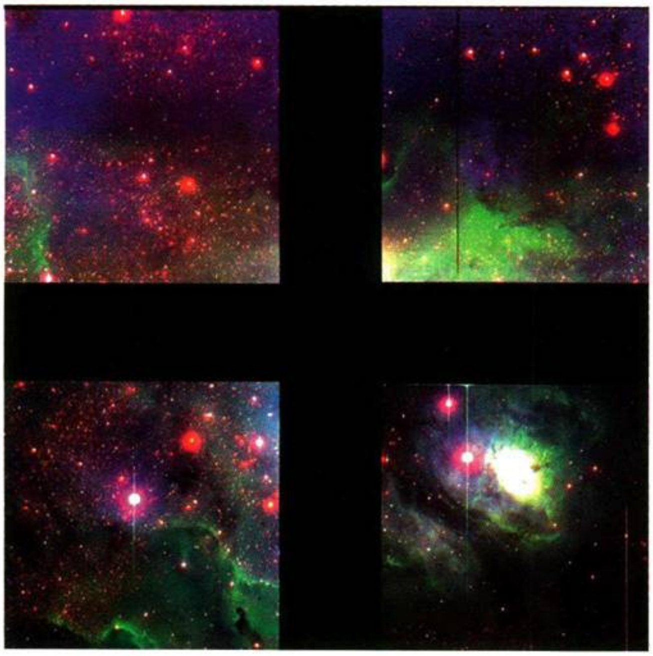


Gary Bernstein (Univ. of Michigan), Tony Tyson and Ian Dell'Antonio (Bell Labs)

The BTC camera captured this mosaic of the Lagoon Nebula. The image covers the entire wavelength range from ultraviolet to near-infrared. The black *cross* is a region not imaged by the camera.

Gary Bernstein (Univ. of Michigan), Tony Tyson and Ian Dell'Antonio (Bell Labs)

This detailed image captures a small portion of the image at the lower right.

ciently collect light at all wavelengths between ultraviolet and infrared.

The BTC consists of four square-shaped CCDs, each measuring 5 centimeters on a side. With this relatively large size, a single BTC exposure covers one-half degree across, an area of sky slightly larger than a full Moon. Each BTC exposure reigns in 35 megabytes of data, enough to fill 25 floppy disks. This is 16 times more data than cameras could generate just a few years ago.

"This camera compliments the Hubble Space Telescope because of its wide coverage of sky and great sensitivity at all wavelengths," says Tyson, who has helped test the BTC on the 4-meter Blanco telescope at the Cerro Tololo Observatory in the Chilean Andes. Bernstein and Tyson will use the BTC to search for huge concentrations of dark matter through its subtle gravitational lensing effect on light from more distant galaxies.

The BTC makes this possible because of its ability to cover tens of square degrees at high sensitivity in only a few months. Other astronomers will use the BTC to search for extremely distant galaxies, extrasolar planets, and supernovae halfway across the universe.

Ho Hum, More New Planets

California-based planet hunters Geoff Marcy and Paul Butler continue to add to the inventory of planets outside the solar system. In early July they announced a new planet with a mass of at least 0.6 Jupiter orbiting the F7 star Upsilon (υ) Andromedae, a slightly larger and hotter version of the Sun about 55 light-years away. The planet orbits the star in a near-perfect circle once every 4.61 days, putting it only 0.05 astronomical units from the star. This is the fourth Jupiter-mass planet discovered orbiting very close to its host star. "People just a few months ago thought the 51 Pegasi planet was a freak, but you can't say that anymore," says Marcy.

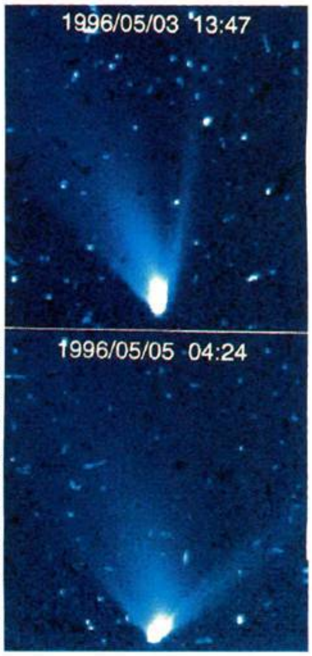
Marcy and Butler also announced that a second planet might be orbiting the star Rho^1 (ρ^1) Cancri (see "Another Extrasolar Planet," AstroNews, July 1996). The new planet has a minimum mass of about five Jupiters and orbits the solar-type star at a distance of 5 to 10 AU. Because the planet takes about 20 years to go around the star, and Marcy and Butler only have nine years of data, it will take another five or 10 years to know for sure if it's really a planet. The previously announced planet orbiting Rho^1 Cancri, which is almost certain to exist, has a mass of at least 0.8 Jupiter and orbits at only 0.11 AU from the star.

Meanwhile, Michel Mayor and Didier Queloz of the Geneva Observatory in Switzerland are keeping close tabs on five good brown dwarf candidates that weigh in with the mass of at least 15 Jupiters. Stay tuned.

More from Hyakutake

Exciting results continue to pour out of research done on the Great Comet 1996. Some astronomers used the American Astronomical Society's summer meeting in Madison, Wisconsin, to announce some exciting discoveries made during the comet's March flyby of Earth.

We now know that comets like Hyakutake formed in a very chilly part of the solar system's protoplanetary cloud, this



Naval Research Laboratory, NASA, and ESA

Images taken from the orbiting solar observatory SOHO show how Comet Hyakutake formed a resplendent dust tail *while* passing the Sun. Astronomers will deduce the tail's composition by looking at its shape.

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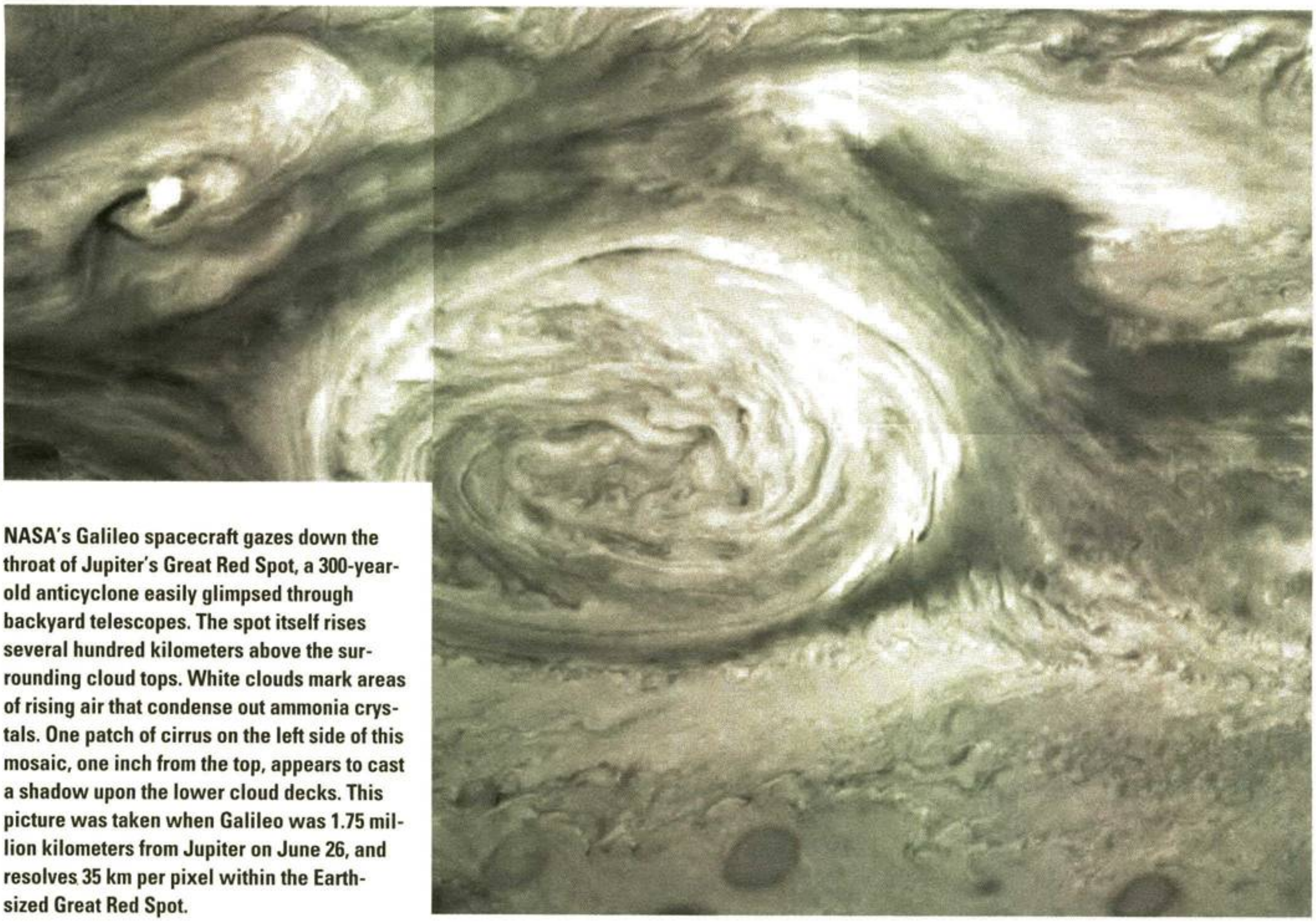


NASA/JPL

NASA's Galileo spacecraft gazes down the throat of Jupiter's Great Red Spot, a 300-year-old anticyclone easily glimpsed through backyard telescopes. The spot itself rises several hundred kilometers above the surrounding cloud tops. White clouds mark areas of rising air that condense out ammonia crystals. One patch of cirrus on the left side of this mosaic, one inch from the top, appears to cast a shadow upon the lower cloud decks. This picture was taken when Galileo was 1.75 million kilometers from Jupiter on June 26, and resolves 35 km per pixel within the Earth-sized Great Red Spot.

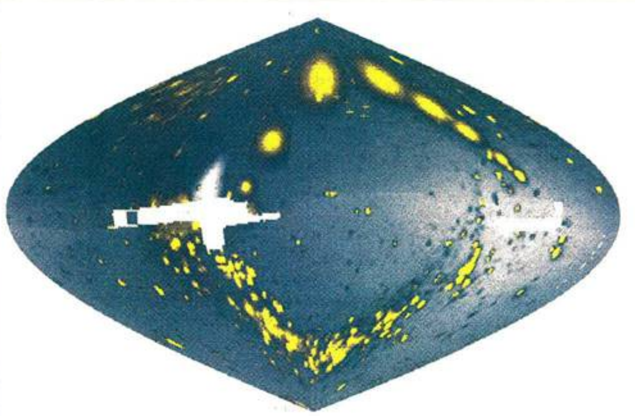
according to Michael Mumma of the Goddard Spaceflight Center. He used an infrared telescope in Hawaii to detect acetylene and ethanol on a comet for the first time.

When the comet's nucleus formed billions of years ago, its acetylene, quite common in interstellar dust clouds, condensed out on dust grains no warmer than a frigid 20° K. Radiation from a newly-lit Sun eventually reacted with acetylene to form ethanol, also detected in abundance on Hyakutake. The hydrogen atoms needed to form ethanol only existed closer the Sun. But if the proto-Hyakutake had ventured too close to the Sun, its acetylene would have been vaporized.

Based on this, Mumma theorizes that Hyakutake's building blocks arose in interstellar space before migrating to an area no closer than Jupiter's distance from the Sun.

Hyakutake was also more active during its March flyby than most other comets, says French Astronomer Jean-Loup Bertaux. He used an instrument on an orbiting solar observatory that normally monitors the Sun's solar wind to indirectly measure the amount of water Hyakutake gave off.

At its peak, the comet created a cloud of hydrogen 16 million kilometers across, which translates into a water loss rate of six tons a second. If the comet's radar-derived diameter of two kilometers is valid, it would mean Hyakutake's entire surface



Jean-Loup Bertaux, Service d'Aeronomie du CNRS

An all-sky instrument on SOHO captures a giant hydrogen gas cloud surrounding Comet Hyakutake as it moves through the inner solar system. At its most active, the comet was dumping six tons of water each second to create a hydrogen cloud 16 million kilometers wide.

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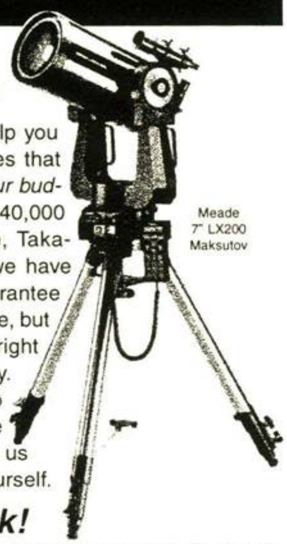

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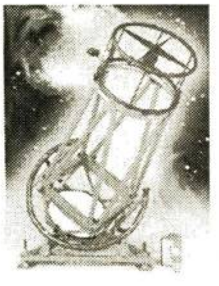

The **L-5 Systems JC524**, shown to the left, is a 24" f/3.8 split ring equatorial reflector with a go-to computer drive – at a price nearly $10,000 less than another manufacturer's 25" model. At $15,250, the JC524 is not exactly cheap, but it may be one of the best buys in large aperture astronomy!

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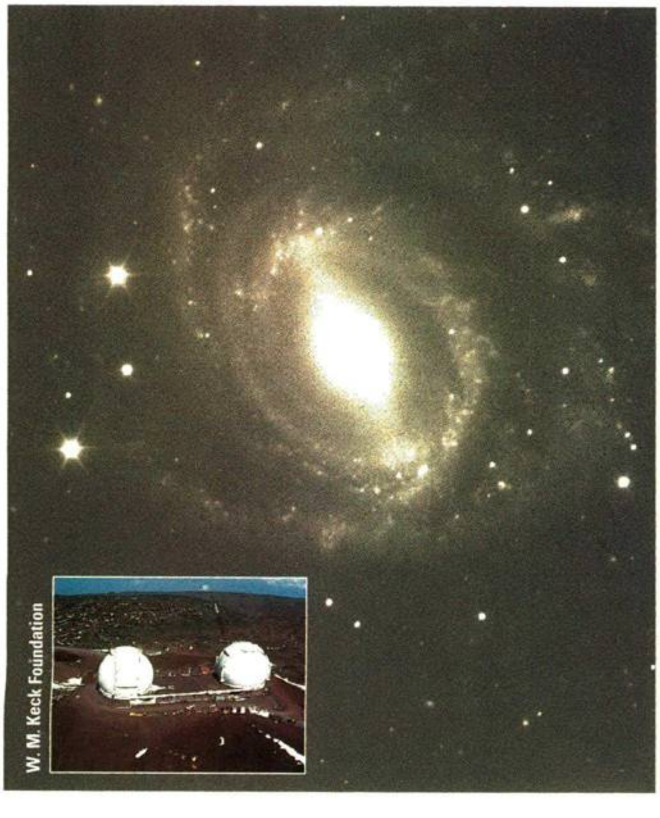
was shedding material. In comparison, only 12 percent of Halley's surface was active at any given time.

Astronomers also used the same solar observatory to deduce the physical nature of Hyakutake's dust tail. Pictures taken with a camera that photographs the Sun's corona captured images of dust streaming from the comet as it rounded the Sun after May 1. The Sun's gravity "sorted" these dust particles by size and type of material into a broad, fan-shaped dust tail. By examining fan's size and orientation, astronomers will deduce what kind of material, and how much of it, made up the non-ice portion of the comet's nucleus.

First Light for Keck II

The identical twin of the world's largest optical telescope has just come online. The 10-meter Keck II Telescope, located just 85 meters from the five-year-old Keck I Telescope on the summit of Mauna Kea on Hawaii's big island, was dedicated on May 8. Both Keck telescopes use 36 hexagonal-shaped mirrors to form a mirror with an effective diameter of 10 meters. Later this decade, Keck II will be fitted with an adaptive optics unit to compensate for atmo-


Tom Bida, Judith Cohen, and the W. M. Keck Foundation

W. M. Keck Foundation

NGC 5850, 150 million light-years away in Virgo, appears in this image from the newly dedicated Keck II Telescope, which appears alongside its twin, Keck I, in the inset.

No Kuiper Comets?

In June 1995 a team of astronomers led by Anita Cochran of the University of Texas at Austin announced that the Hubble Space Telescope had spotted a vast reservoir of comets lurking beyond Neptune in a region called the Kuiper Belt. Hubble, it was said, spotted roughly 30 objects the size of comet nuclei in the Kuiper Belt (see "First Drops in a Comet Reservoir," AstroNews, October 1995). But Cochran's team now reports that a second look by Hubble has come up empty, a result that might have been due to instrument noise. The team will look again later this year.

Close Call

Earth had a close call on May 19, when asteroid 1996 JA$_1$ zipped by the planet at a distance of only 453,000 kilometers, which is slightly farther than the Moon. JA$_1$ was the sixth closest Earth-approacher on record, and measured some 500 meters across, 10 times the size of the impactor that made Arizona's famous Meteor Crater. If JA$_1$ had smashed into Earth, it would have caused regional (but not global) devastation.

Takuo Kojima

Asteroid 1996 JA$_1$, seven hours before Earth flyby.

Longer Days Ahead

Astronomers have known for more than a century that tidal interactions cause the Moon to slowly drift farther from Earth, causing Earth's rotation to slow down. Now, a team of geologists led by Charles Sonett of the University of Arizona has discovered fossil evidence of this effect. By analyzing 900 million-year-old rock deposits that recorded the advance and retreat of tides, the geologists found that a year back then had 482 days, meaning each day lasted only 18.2 hours.

Blowing in the Solar Wind

The joint NASA/European Space Agency SOHO solar probe has discovered seven new elements in the solar wind: phosphorus, chlorine, potassium, titanium, chromium, manganese, and nickel. "We are filling in the periodic table of solar wind observations," says SOHO investigator Antoinette Galvin of the University of Maryland. SOHO has also discovered a host of new isotopes. The composition of the solar wind tells astronomers about the composition of the nebula from which the Sun and planets formed.

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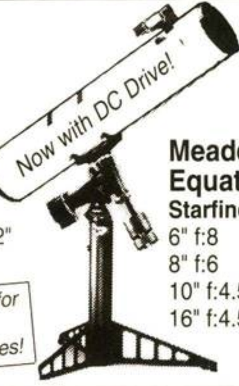
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spheric blurring. In four years, astronomers will combine the light from the two telescopes to create an optical interferometer, simulating the resolution of an 85-meter telescope. NASA will use the pair to search for extrasolar planets.

No M31 MACHOs?

Last January, an international team of astronomers reported that roughly half of the dark matter in the Milky Way's halo might consist of burned-out stars between ⅒ and 1 solar mass (see "A MACHO Galaxy?" AstroNews, May 1996). These invisible, massive objects are collectively known as MACHOs, short for MAssive Compact Halo Objects. The team reached their conclusion by observing how MACHOs "microlens" light from stars in the Large Magellanic Cloud (see "The Dark Side of the Galaxy," page 41).

Now Arlin Crotts and Austin Tomaney of Columbia University are reporting microlensing results using the Andromeda Galaxy (M31) as a backdrop instead of the Large Magellanic Cloud. During their search, Crotts and Tomaney observed millions of stars in M31. They detected 2,000 variable stars, but only two possible instances of microlensing. If the two microlensing events are genuine, they would both be the result of objects slightly less massive than the Sun.

Perhaps more important is what Crotts and Tomaney did not observe. They did not detect a single microlensing event that would be due to MACHOs ranging in mass between a Jupiter and a brown dwarf. "We pretty much rule out substellar mass objects," says Crotts. This result suggests that the bulk of the mass in M31's halo takes the form of black holes or exotic, subatomic particles.

AMATEUR NEWS

Universe Lands in Sunny California

ASTRONOMY teamed up with the Astronomical Society of the Pacific to sponsor Universe '96, an annual event that this year featured 32 different speakers from amateur and professional astronomy, as well as an exhibitor fair that featured more than three dozen vendors. Just under a thousand San Francisco Bay-area visitors attended the weekend gathering at the Santa Clara Westin Hotel on June 21 and 22.

Planet searcher Geoff Marcy was on hand to share the latest techniques he uses to detect worlds around other stars. Marcy hinted that his team would announce many more new discoveries before year's end. Project Phoenix Director Jill Tartar presented her team's progress in using radio telescopes to find the radio signatures of intelligent life around 209 solar-type stars in Southern Hemisphere skies. Within the next year, Project Phoenix turns its attention to a Northern Hemisphere survey.

Other professional astronomers offered many interesting insights into programs they are undertaking. Looking closer to home for extraterrestrial life, NASA-Ames astronomer Chris McKay would have robotic rovers scour ancient basins on Mars for evidence of fossils. JPL research astronomer Steve Ostro related how he uses giant radio dishes on Earth, like the Arecibo Radio Observatory in Puerto Rico, to shine radio waves on passing asteroids to deduce their shapes and construct crude surface maps.

ASTRONOMY: John Shibley

Extrasolar planet sleuth Geoff Marcy (right) meets with the audience before his talk at Universe '96. Marcy explained to more the 600 listeners how he and his colleagues find planets around other stars.

On the amateur front, astrophotographer Jack Newton showed off his latest astrophotos and deep-sky author Robert Garfinkle presented plans for starhopping tours in different areas of the night sky. ASTRONOMY's Dan Koehler and John Shibley respectively gave advice on how to kindle a child's interest in astronomy and on ways of avoiding costly astrophotography mistakes.

Next year's Universe comes to downtown Chicago's Hyatt Regency on the Riverwalk between June 27 and July 2. The gathering will be cohosted by the Adler Planetarium and offer a teachers' astronomy workshop. Write the Astronomical Society of the Pacific at 390 Ashton Avenue, San Francisco, CA 94112, for more information.

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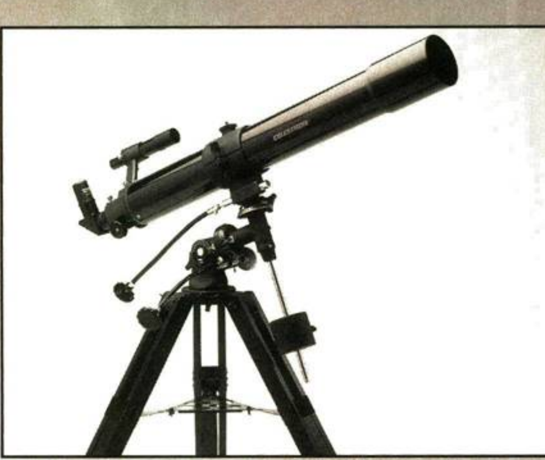
Firstscope 80 EQ – The **best buy** in refracting telescopes – high performance and unbeatable price.

The **Firstscope 80 EQ** telescope is a good choice for the more serious beginning astronomer. An 80mm (3.1") aperture. The objective is an air-spaced achromat designed to yield the finest images available in this class of instrument. It has a 910mm focal length (f/11.4).

The equatorial mount is stable and includes setting circles in both axes as well as slow-motion cables in both axes for easy tracking. The wood tripod is adjustable in height and includes an accessory tray.

For astronomy you can enjoy breathtaking views of the Moon, Saturn with its ring *structure*, Jupiter and its belts and hundreds of deep-sky objects including galaxies, nebulae and star clusters. With a solar filter (optional) you can observe activity on the Sun. For terrestrial use, enjoy vistas from view homes or take your instrument out in the field to take advantage of our natural environment up close.

Standard accessories include a 6x30 Finderscope, 1¼" Focuser, 25mm SMA Eyepiece – 1¼" (36x), Star Diagonal – 1¼". Weight is 24 lbs.



4" REFRACTORS

Celestron offers two models of 102mm (4") equatorial refractor telescopes. These telescopes are for the more serious astronomer who appreciates superb optics and ultra-stable mounts.

The Great Polaris (GP) German equatorial mount is standard. Both axes have precision 144-tooth lapped worm gears for very smooth motion. The adjustable height, very rigid wood tripod has excellent vibration dampening characteristics and has a handy accessory tray.

The GP mount has a built-in illuminated polar alignment scope for fast polar alignment.

The premium optics of the **GP-C102** are made in Japan to rigid standards. It has a focal length of 1000mm (f/9.8). The **GP-C102-ED** model features Super ED glass to yield exquisite images of very high contrast and resolution with virtually no chromatic aberration. The ED unit has a focal length of 920mm (f/9) and has multi-coatings.

Standard accessories (the same on both models), include a 20mm Eyepiece – 1¼", 6x30 Finderscope with an 8° field and a Star Diagonal – 1¼". Weight is 39 lbs.

Optical tube assemblies of the 4" refractors are available separately and include tube rings, mounting plate and finderscope.

CELESTRON REFRACTING TELESCOPES:

The 60mm (2.4") refractor is the most popular telescope size for the beginning astronomy enthusiast or for casual gift-giving. It can introduce newcomers to the exciting hobby of astronomy at an affordable price.

FIRSTSCOPE 60

A 700mm focal length (f/11.7) telescope which contains all glass optical components with coated optics.

The glossy black telescope optical tube is made of aluminum. The sturdy altazimuth mount has a slow-motion control rod for vertical adjustments. The rigid, adjustable wood tripod includes an accessory tray.

Standard accessories include a 20mm H – .96" Eyepiece (35x), 6mm SR – .96" Eyepiece (117x), 2x Barlow Lens – .96", 5x24 Finderscope and a 90° Diagonal.

FIRSTSCOPE 60 DELUXE

The same as the Firstscope 60 except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25 SMA (28x) and 10mm SMA (70x).

Celestron offers two 60mm equatorial refractors – the Firstscope 60 EQ and the Firstscope 60 EQ Deluxe.

FIRSTSCOPE 60 EQ

Similar to the Firstscope 60 but the focal length for this telescope is 900mm (f/15).

Standard accessories include a 20mm H – .96" Eyepiece (45x), 12.5mm H – .96" Eyepiece (72x), 2x Barlow Lens – .96", 6x24 Finderscope and a 90° Diagonal. Weight is 11 lbs.

FIRSTSCOPE 60 EQ DELUXE

The same as the Firstscope 60 EQ except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25mm SMA (36x) and 10mm SMA (90x).

The 1¼" accessories give you sharper images, a wider field of view and better eye relief. Weight is 11 lbs.

Celestron offers a premium grade 80mm (3.1") altazimuth refractor – **The Premium 80.** The premium built optics are made in Japan.

The Premium 80 is an ideal first telescope for the more serious beginning astronomer or terrestrial observer.

Its easy-to-use altazimuth mount includes slow-motion controls in both axes with flex cables allowing quick and easy pointing and tracking. The supplied attractive and very sturdy wood tripod is adjustable in height.

Standard accessories include a 26mm multi-coated Plössl – 1¼" Eyepiece (35x) for a wide field of 1.4°, high quality 6x30 Finderscope and a versatile 45° Erect Image Diagonal – 1¼". Weight is 18 lbs.

CELESTRON® *For more detailed information on these telescopes, contact a Celestron dealer or Celestron.*

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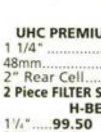

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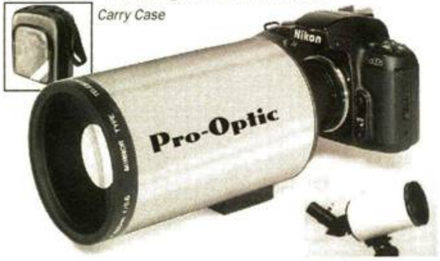

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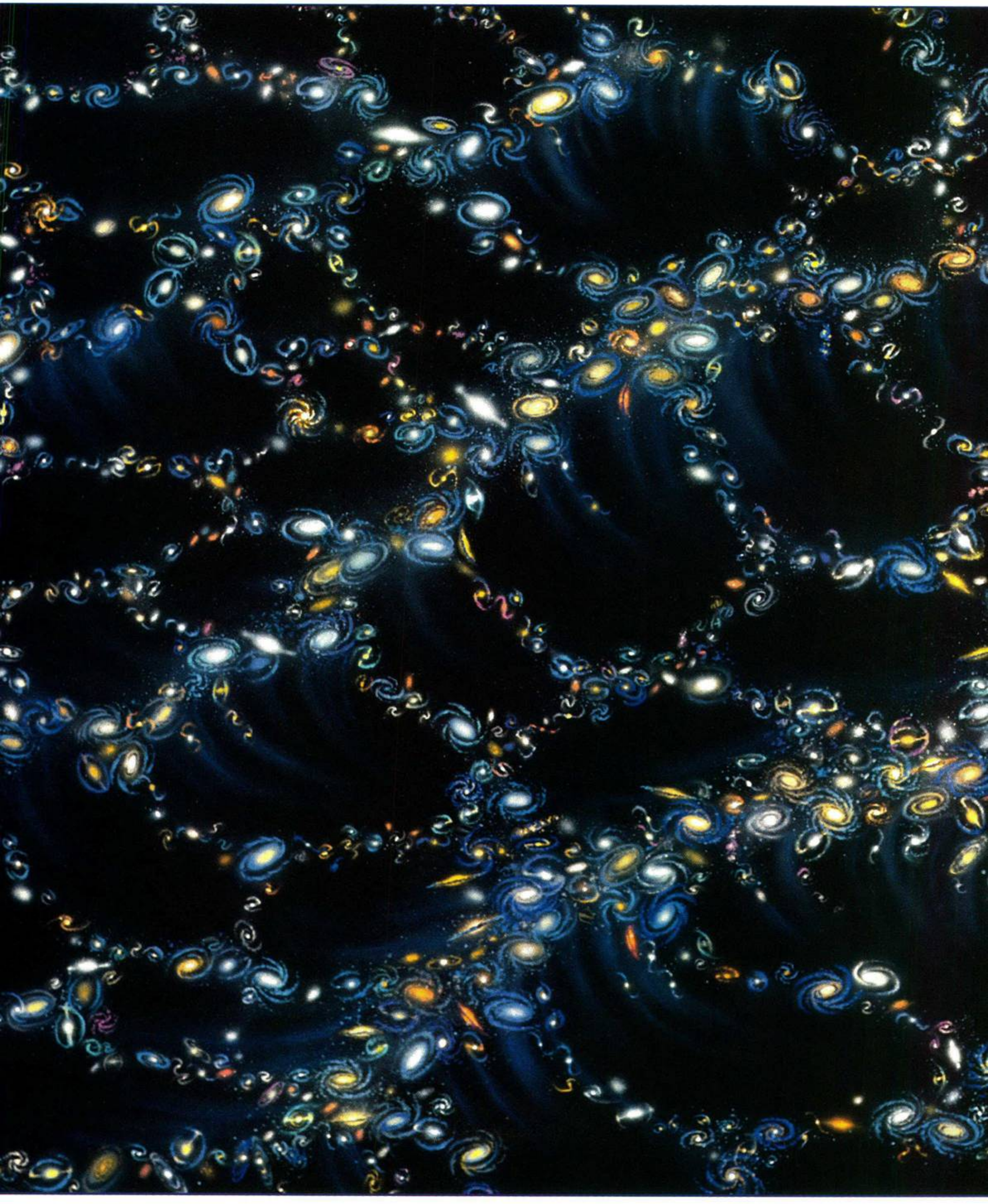


Lynette Cook

Dark Matter AND THE Fate OF THE Universe

by Jeff Kanipe

To paraphrase Voltaire, if dark matter did not exist, it would have to be invented. For without its gravitational glue, the universe would literally have scattered soon after the Big Bang, and the beautiful reticular structure of galaxy clusters seen throughout the universe today would have never been forged. Which is to say we wouldn't be presenting this special issue on dark matter and the challenges, and hope, it poses modern cosmology.

In the 1930s, astronomers studying the motions of galaxies in clusters noted that, given their observed velocities and apparent masses, these vast structures should have dispersed long ago. Apparently, something had retained a vice-like grip on them, keeping them assembled. A similar situation was observed at smaller scales in spiral galaxies beginning in the 1970s. Contrary to Keplerian law, spirals rotate just as fast at the outskirts of their visible disks as they do near their inner regions. How can they do this without flying apart?

And just this year, studies of the motion of a satellite dwarf galaxy orbiting the Milky Way showed that it has maintained its shape after billions of years. How is this possible, since many dwarf galaxies are little more than extremely loose aggregates of stars?

The inescapable conclusion is that visible matter constitutes a small minority of the universe, making up anywhere between 1 and 10 percent of its total mass. That means that at least 90 and as much as 99 percent of the universe exists in some alternate form of matter that has yet to be directly detected. On galactic scales, then, each galaxy must be fixed in its own block of dark-matter resin, like a mosquito in amber, while on cosmological scales, galaxy clusters are to sea foam as dark matter is to the ocean.

The quest for dark matter is one of the most important tasks in cosmology today. It literally determines the density, or perhaps I should say, *destiny*, of the universe. For it is the density of the universe that is critical in determining whether the galaxies will recede from each other forever, or at some point in the remote future halt their outward flow and fall back together. If the universe contains enough dark matter, that would do the trick, but one can't very well determine whether the universe will expand forever or collapse without accounting for 90 to 99 percent of its contents!

It seems absurd that astronomy, the oldest science, cannot tell us what the universe is made of. Nevertheless, as our dark-matter special demonstrates, what you see of the universe from your backyard is a modicum of what it contains. As the research continues and the observations accumulate, we can only hope that scientists will one day bring the nature of dark matter to light. After all, the very fate of the universe depends on it. □

Jeff Kanipe (jkanipe@astronomy.com) is ASTRONOMY's managing editor.

THE New Dark Age OF Astronomy

Astronomers can't answer a simple question that a child might ask: What is the universe made of?

by Marcia Bartusiak

A diverse assortment of telescopes points at the heavens and gathers data that, more often than not, clarify and extend our accepted model of the universe. But at times a finding pops up that generates new challenges. It is a piece of the cosmic puzzle that never quite fits in. The greatest moments in astronomy are often foreshadowed by these nagging uncertainties, annoying loose threads that hang off the tight weave of a long-established theory.

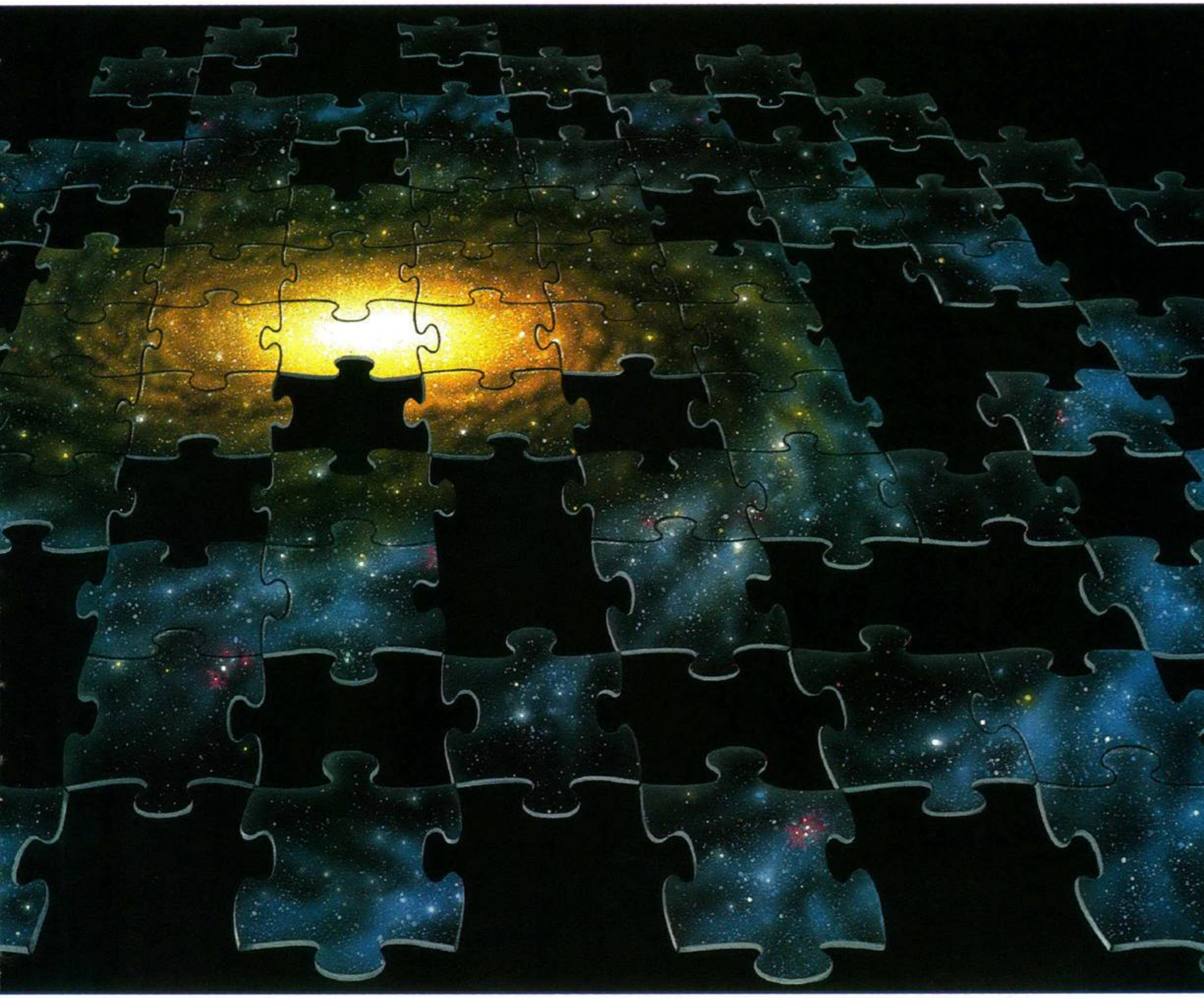
Such crises in astronomy periodically wax and wane over the centuries. Take epicycles, for example. Ptolemy, the noted second century astronomer and geographer, proclaimed that the universe was flawless and unchanging, with a motionless Earth poised prominently in its center. The sky was an intricate maze of wheels within wheels – epicycles – that soundlessly revolved around God's central creation, humanity.

Ptolemy's vision held sway for some 1,400 years. But as planetary movements were studied with more and more accuracy, this complicated picture began fraying at the seams. In 1543 the Polish clergyman Nicolas Copernicus offered a new paradigm, a novel way of looking at old, familiar facts. He moved the Sun to the center of the solar system. Ptolemy's universe at last crumbled in 1609, when German astronomer Johannes Kepler discovered that planets trace elliptical orbits, thus making epicycles irrelevant once and for all.

A few centuries later astronomers were baffled by wispy, spiral-shaped patches of light in the nighttime sky that could not be resolved into individual stars. For decades they heatedly debated the true nature of these enigmatic spiral nebulae. Aided by the largest telescope in its day, the massive 100-inch reflector atop California's Mount Wilson, Edwin Hubble finally proved in the 1920s that the misty objects were separate "island universes." Our home galaxy, the Milky Way, was but one among billions of other galaxies spread throughout space. The cosmos, cozily centered on us for so long, opened up a millionfold.

And now another mystery is tugging at observers' shirtsleeves. Just four decades ago astronomers were convinced that a final tally of the universe's contents was nearing completion. They knew that hydrogen and helium originated some 15 billion years ago in a burst of elemental cooking that took but minutes during that primordial explosion known as the Big Bang. More complex atoms, such as oxygen, carbon, and nitrogen – the stuff of life – emerged later after the birth of stars, whose fiery interiors construct these weightier elements.

More recently, however, clues have been swiftly emerging that a dark, hidden universe lurks beside this luminous cosmos so long studied with telescope and spectroscope. No one expected this turn of events. It's thrusting astronomy back into a "dark age." Each and every galaxy in the universe could be but an inconsequential raft floating within a much vaster sea of unseen matter.



Lynette Cook

This material emits not one glimmer of detected light, yet it could account for more than 90 percent of the universe's mass. "A 4-year-old might ask the simple question, 'What is the universe made of?' And we can't answer it," says Fermilab cosmologist Rocky Kolb.

A great deal hinges on figuring out the answer to this straightforward question. Determining the composition of this ocean of dark matter has the potential to alter our views of the cosmos: how galaxies were born; how fast the universe is expanding; and whether our universe will end in a fiery conflagration or limp forever outward to icy nothingness.

The first hint that something was amiss in the inventory of the universe's contents actually appeared more than 60 years ago. In 1933 Caltech astronomer Fritz Zwicky examined the motions of galaxies within the famous Coma Cluster. He noticed that the galaxies were moving rapidly within the cluster. After adding up all the light emitted by the galaxies, he realized that there was not nearly enough visible, or luminous, matter in the form of stars and nebulae to gravitationally bind the speeding galaxies to one another. But the cluster still remained very much intact. Zwicky had to assume that some kind of unseen matter – a missing mass – pervades the Coma Cluster to provide an additional gravitational glue. Something else was out there, a dark, nameless matter that outweighed the luminous mass ten times over.

The mystery of the dark matter didn't make much of a splash during those Depression years. Most astronomers believed the dilemma would disappear once theorists figured out the motions of galaxies in more detail. By the 1970s, however, the problem was brought closer to home when radio and

Luke Dodd

Dark nebulae do *not* constitute the universe's dark matter. When astronomers inventory the universe's visible contents, they include dark nebulae such as the Coalsack in the southern constellation Crux.

optical astronomers revealed that the problem wasn't just in clusters.

After studying hundreds of individual spiral galaxies, Vera Rubin and her colleagues at the Carnegie Institution of Washington established that the outer parts of these galaxies were rotating around their galactic centers as fast as the inner parts, in direct violation of Kepler's laws. Indeed, the spiral galaxies are spinning so fast that they have to be embedded in vast spheres of additional material. Otherwise, their outer stars would zip completely out of the galaxy, like a discus cast out of the hand of a whirling athlete. "Nature has played a trick on astronomers, for we thought we were studying the universe," says Rubin. "We now know that we were studying only the small fraction of it that is luminous." But what makes up the rest of it?

For many astronomers, the solution is obvious: The dark matter, they say, is simply composed of ordinary matter, but in a form that is difficult to spot. They're spurred on by a fascinating concurrence; all the visible and estimated dark matter taken as a whole just about matches the maximum number of "baryons" or ordinary matter – the protons and neutrons that make up atoms – that scientists think were forged in the first second of the Big Bang. That's a telling match-up, strong evidence that the dark matter can be made out of familiar but not-easily-detectable celestial objects, such as extremely faint white-dwarf stars, black holes, or "failed stars" called brown dwarfs. According to this scheme, 10 percent of the ordinary matter born in the Big Bang turned into objects that shine brightly like the glowing lights on a Christmas tree, while the other 90 percent remains hidden in a dark halo surrounding most galaxies.

Searches for this great pool of matter have been underway in recent years, and initial results are encouraging. Earlier this year astronomers reported the first signs that a multitude of burned-out white-dwarf stars might be surrounding our galaxy. These so-called MACHOs (astronomers' whimsical acronym for MAssive Compact Halo Objects) could account for a sizable chunk of the Milky Way's missing mass.

But that's only part of the dark matter story. The latest and most fashionable cosmological theories suggest that the dark matter comprises, not ten times as much mass as the luminous stars and galaxies, but up to a hundred times more. Cosmologists believe this extra mass arose when the universe experienced a fleeting moment of superacceleration at its birth – a period of "inflation." Instead of a continual and steady expansion, the cosmos allegedly tore outward briefly like a spaceship on warp drive, leading to a flood of additional particles and radiation.

But there's a catch: No one has yet detected the presence of such huge amounts of matter in the universe. For the moment, this idea is like a theoretical wish, and many astronomers are not yet convinced that inflation ever happened.

If this extra stuff truly exists though, it can't be ordinary matter. The Big Bang couldn't have cooked up that many protons and neutrons. That turns the dark matter mystery, once the sole province of astronomy, into a special challenge for particle physicists. They must come up with new and exotic species of particles to serve as this additional cosmological dark matter.

A particle known as the neutrino (Italian for "little neutral one") is a popular candidate, and for good reason: it's already known to exist. But no one yet knows for sure whether these slippery particles – they can pass through entire planets like ghosts – have any mass, at least enough substance to serve as the cosmologists' dark matter. Physicists at the Los Alamos National Laboratory have recently announced that they've found evidence for a massive neutrino in a particle accelerator experiment, but this result awaits confirmation.

Meanwhile, theoretical physicists are continually dreaming up new particles. And if these particles prove to be more than hypothetical, they might be ideal for explaining the cosmological dark matter. For instance, in dealing with certain aspects of the strong nuclear force (the force that keeps atomic nuclei from flying apart), physicists have predicted the existence of the axion, a particle that was named after a laundry whitener. Even though an axion is calculated to be 100 billion times lighter than an electron, the particle would be so insubstantial that trillions could be stuffed into every cubic inch of space around us. But, taken over the entire cosmos, all those axions would add up to some substantial matter.

There are also a number of particles that pop up in equations as theorists try to unify nature's various forces. In these schemes, every particle already known to exist has a partner. The Z particle has its Zino, the W particle its Wino, the photon its photino, and the quarks their squarks. Collectively, these have come to be known as WIMPs, for Weakly Interacting Massive Particles. Each would be roughly as heavy as ten or more protons, yet still, like the featherweight axion, be rudely indifferent to ordinary matter.

Physicists take this idea very seriously. Indeed a number of groups have constructed special instruments in hope of capturing one of these exotic dark matter particles. Others are sifting through the debris of high-energy collisions in particle accelerators, which can briefly recreate the conditions of the early universe. Some physicists think the footprints of WIMPs have already turned up in the ashes of such collisions.

Which avenue is most fruitful – searching for MACHOs or WIMPs – will be known only in hindsight. Will the dark matter consist solely of a hidden armada of white- or brown-dwarf stars? Or is there an extra component of exotic elementary particles spread throughout the cosmos as well?

Tony and Daphne Hallas

If dark matter didn't exist, galaxy clusters such as the great Virgo Cluster (above) would fly apart.

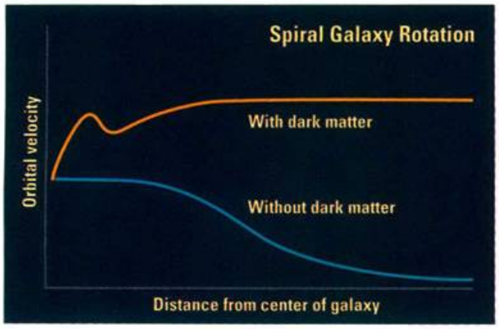
If the dark matter is largely made up of undetected particles, uncovering the dark matter mote could be as momentous as the discoveries of the electron, proton, and neutron — maybe more so. Such a particle, unlike the stuff that makes up people, suns, and planets, would be the predominant substance of the cosmos. "It would be the ultimate Copernican revolution," says Bernard Sadoulet, director of the Center for Particle Astrophysics at the University of California in Berkeley. We'd have to come to terms with the possibility that the very atoms in our bodies are but a minor constituent in the universe's essential makeup.

Tremors surround us. Zwicky first noticed that a large component within a cluster of galaxies was missing; decades later, the rumbles got louder when Rubin deduced that spiraling galaxies were immersed in a dark, unnamed material. Do these tremors portend a bigger quake ahead, a temblor that wrenches the center of our universe again, just as the findings of Copernicus and Hubble once did? A few adventuresome theorists are even suggesting that the bulk of the dark matter will be explained in another way altogether, by new physical theories.

I have this dream that there will be a sort of Sherlock Holmes event," says Princeton astrophysicist James Peebles. "Someone will look at this great pyramid of evidence that is building up and exclaim. 'Yes, Watson, I think I see it. By Jove, that must be it.'"

We eagerly await that momentous occasion. ☐

Marcia Bartusiak is an adjunct professor of science journalism at Boston University. This article is based on her most recent book, Through a Universe Darkly (HarperCollins/Avon), which chronicles the dark matter search.



ASTRONOMY: Phil Kirchmeier

Astronomers know that dark matter surrounds spiral galaxies such as NGC 2997 (right) because the outer regions rotate around the galactic center just as fast as the inner regions, in seeming violation of Kepler's laws.

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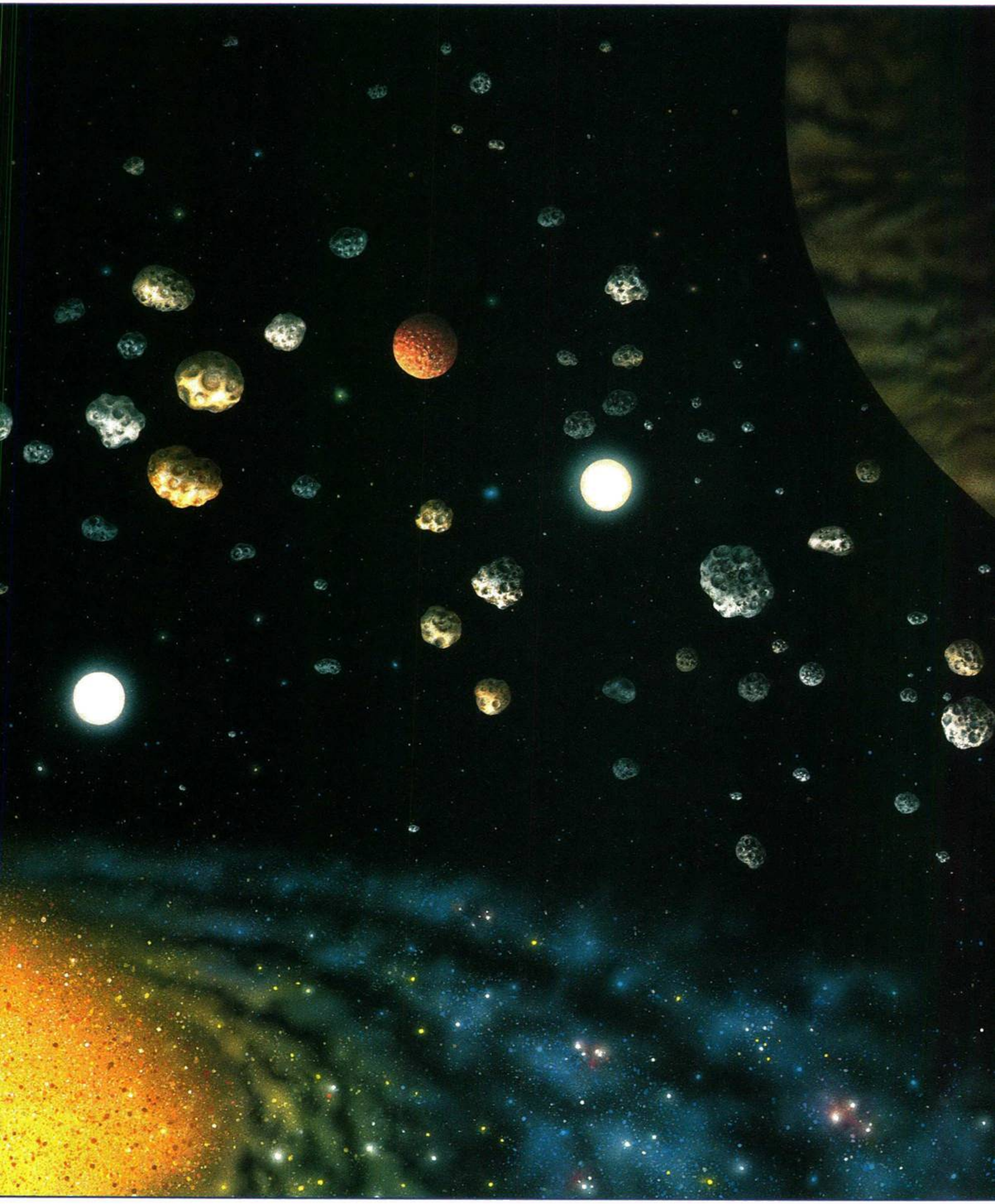


Lynette Cook

THE Dark Side OF THE Galaxy

By the end of this decade, astronomers hope to learn if the dark matter pervading the Milky Way's frontier consists of massive, invisible objects.

by Ken Croswell

We live in a dark galaxy. Although the Milky Way's beautiful disk speckles the night with the glow of countless stars, these same stars mask the Galaxy's dark truth: Most of its mass is invisible, beyond the purview of either human or telescopic eye. Surrounding the luminous disk is an enormous dark halo that stretches for hundreds of thousands of light-years but emits almost no light at all, which means that conventional observations cannot reveal its nature.

"I am completely in the dark about what dark matter is made of," says Princeton astronomer Bohdan Paczynski. "I really have no clue whatsoever, and whatever people claim is just guesswork."

Astronomers know that dark matter surrounds the Milky Way's disk because of the high speed at which stars and gas in the outer Galaxy revolve, as well as from the rapid motions of other galaxies that orbit ours. But the Milky Way's dark halo cannot be made of ordinary stars, which observers could see. Even the faintest such stars — red dwarfs like Proxima Centauri and Barnard's Star — would have been seen by now. And the dark halo cannot be made of gas, because gas would emit detectable radiation. That leaves two broad possibilities for the dark halo's composition: dim astronomical objects and exotic subatomic particles.

If you're an astronomer, you would naturally root for the former, known in the trade as MACHOs, or MAssive Compact Halo Objects, which, though dim, are at least within the range of your experience. A MACHO can have almost any mass, from less than a trillionth of the Sun's up to millions of times the Sun's. From low mass to high mass, possible MACHOs include asteroids; planets, either small (like Earth) or large (like Jupiter); brown dwarfs, stars that have too little mass to ignite their fuel; white dwarfs that have cooled and faded; neutron stars; and black holes ranging from a few times the Sun's mass to millions of times greater.

On the other hand, if you're a particle physicist, you might lean toward some type of exotic subatomic particle, such as WIMPs, or Weakly Interacting Massive Particles. Although WIMPs have yet to be identified, even on Earth, they could exist in such large numbers in the dark halo that they account for all of its mass. But many

Luke Dodd

Astronomers patiently observe 10 to 20 million stars in the Large Magellanic Cloud each night for the telltale brightening and fading of MACHO-induced microlensing.

astronomers don't like WIMPs, because it's hard to relish the thought that most of the Galaxy is made of something that your telescope can't detect.

In a 1986 paper, Paczynski proposed a clever technique that has already given astronomers their first probe of dark matter. If MACHOs populate the dark halo, he said, one would occasionally drift in front of a star in the Large Magellanic Cloud, the Milky Way's brightest satellite galaxy. In so doing, the MACHO's gravity would magnify — or "microlens" — the star's light, bending what would otherwise be diverging light rays together so that, as observed from Earth, the star would appear to brighten, then fade back to its normal brightness. On the other hand, if subatomic particles such as WIMPs make up the dark halo, no microlensing events would be seen.

Possible Dark Halo MACHOs

Object	Mass (Solar Masses)	Typical Duration of Microlensing Event
Massive Black Hole	1 million	200 years
Stellar Black Hole	10	8 months
Neutron Star	1.4	3 months
White Dwarf	0.6	2 months
Brown Dwarf	0.02	2 weeks
Jupiterlike Planet	0.001	2 days
Earthlike Planet	0.000003	3 hours
Large Asteroid	10^{-9}	3 minutes
Small Asteroid	10^{-15}	0.2 second

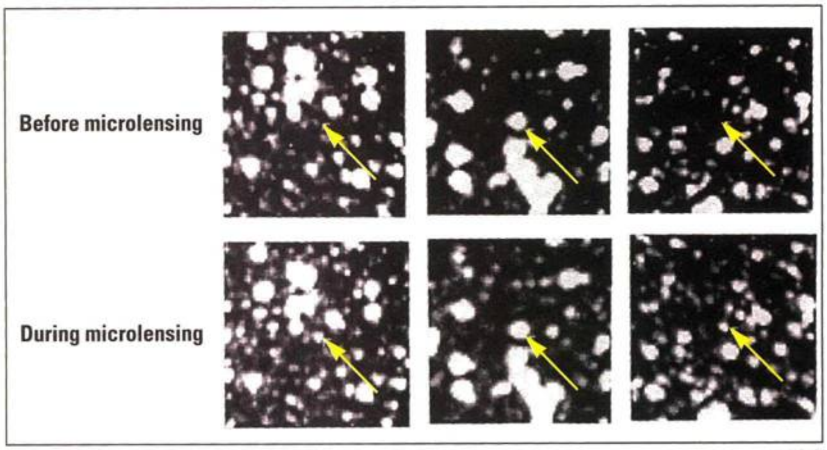
A MACHO Start

In principle, Paczynski's idea was a clean test that would separate the MACHOs from the WIMPs. But it was hardly a plan for the, uh, wimpy, because it called for a huge observational campaign. Even in the best possible case — a dark halo comprised completely of MACHOs — at any time only one star in a million would be getting microlensed. Astronomers would therefore have to monitor millions of stars, night after night, to catch just one instance of MACHO-induced microlensing.

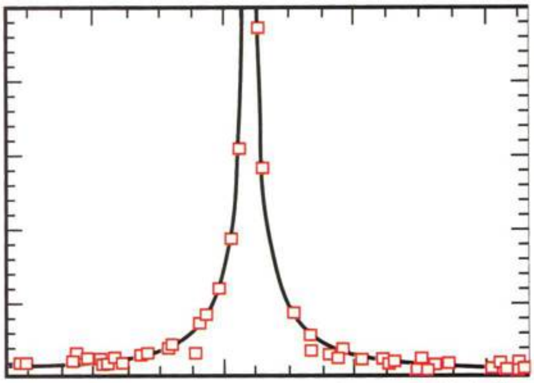
"Before we got started," says Paczynski, "all astronomers I know were extremely skeptical that anything like this could be done. They said we shall be swamped with data, we shall never get it, and there will be all those variable stars." The variations of such stars — Cepheids, RR Lyraes, eclipsing binaries, and more — would far outnumber the rare microlensing events and could even masquerade as those events.

But microlensing events stand out from variable stars in several ways. First, microlensing affects all colors equally. If a MACHO magnifies a star's red light tenfold, then it should do exactly the same to the star's yellow light and its blue light. In contrast, most variable stars vary by different amounts in different colors. Second, the brightness of a microlensed star should not vary again, because the chance that a second MACHO would pass in front of exactly the same star is minuscule.

Four teams of astronomers have now reported microlensing events. The largest group calls itself MACHO and is a collaboration of American, Australian, and British astronomers. Paczynski is affiliated with a second group, based primarily in Poland, called



OGLE



Three stars (top, left to right) in the direction of the galactic bulge brighten as they are microlensed by a foreground object. Microlensing produces a brightening and fading pattern (right), that can be distinguished from variable stars because all star colors are affected equally. The duration of the microlensing event yields information about the mass of the intervening object.

ASTRONOMY: Lee Vande Visse

OGLE, short for Optical Gravitational Lensing Experiment. Two other teams are based in France: EROS (Expérience de Recherche d'Objets Sombres) and a newer group, DUO (Disk Unseen Objects).

Members of these teams need more than just cute acronyms; they also need enormous persistence and patience, because huge numbers of stars must be monitored in order to see any microlensing events. For example, the MACHO team routinely measures the brightnesses of between 10 and 20 million stars per night. The experiment would be impossible without advanced technology — in particular, CCDs to acquire the data and powerful computers to analyze it.

The first searches for microlensing began in the early 1990s. The MACHO and EROS groups observe the Large Magellanic Cloud. The OGLE and DUO groups look at the galactic bulge, the central district of the Milky Way, because ordinary stars in the disk should pass in front of bulge stars and microlens their light. These events could not reveal the nature of the dark matter in the halo, of course, but they would prove that microlensing can be detected, even if the dark halo contains no MACHOs.

In the fall of 1993, the MACHO team reported its first success, with the detection of a microlensing event in the direction of the dark halo, and the EROS team announced two such events. Meanwhile, OGLE reported a microlensing event toward the bulge. With these announcements, a wave of euphoria swept over astronomers, for they had finally "seen" some of the mysterious dark matter that dominates the Galaxy. Many pundits proclaimed that the heroic MACHOs had won their battle with the evil WIMPs — which astronomers can never hope to detect — and that the dark halo was made entirely of MACHOs.

But such claims were misguided. "Quite a lot of people jump to conclusions before the experimental groups are willing to reach those conclusions themselves," says Charles Alcock, a member of the MACHO team who works at the Lawrence Livermore National Laboratory in California. "In our first paper, we published the discovery of one event, and an enormous amount of speculation was based on that one event, plus two events of lower quality from the EROS group. And it was entirely premature."

Not only were such statements wrong, but they now appear to have been based on faulty data. Two of the three dark-halo MACHOs reported in 1993 are under attack, by no less than Paczynski himself. He believes that both of the brightenings announced by the EROS team were actually the antics of variable stars rather than genuine MACHOs.

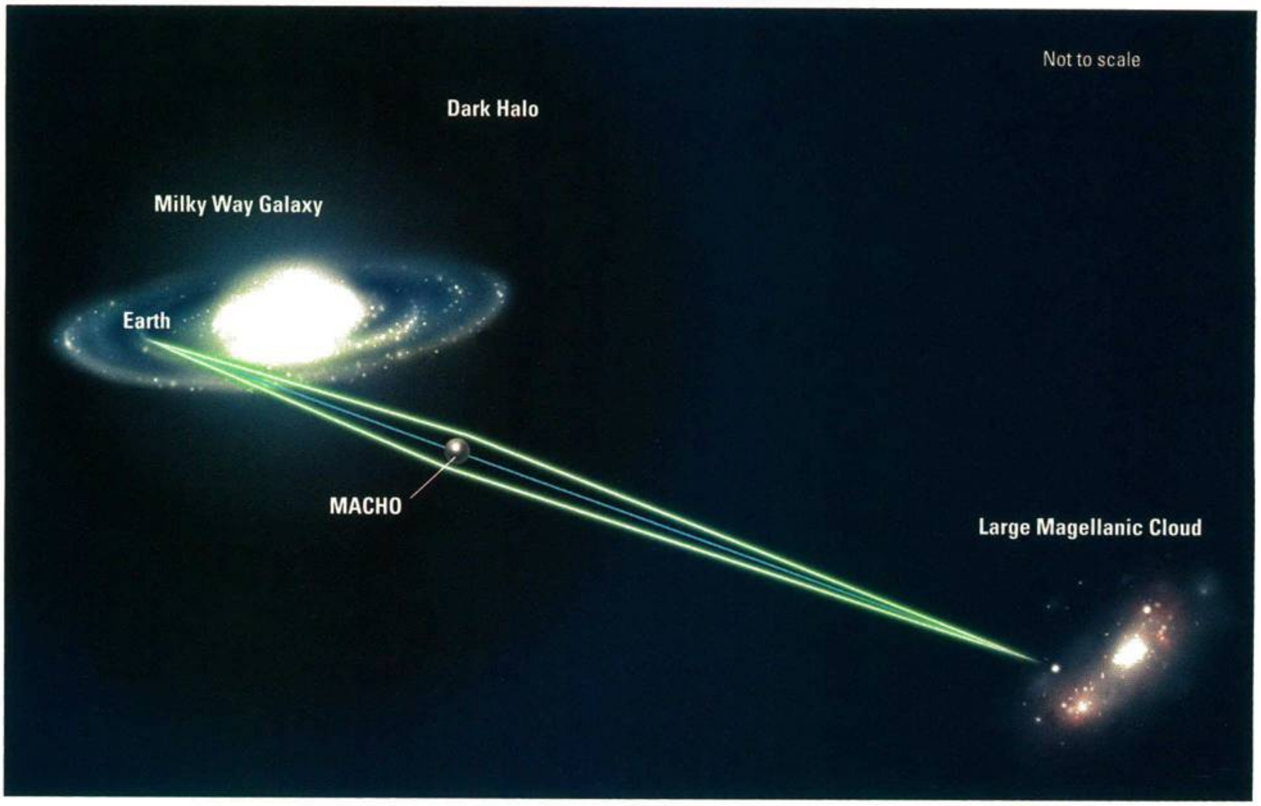
"The whole series of announcements in 1993 was really triggered by the EROS claim," says Paczynski. "The EROS people told the MACHO people that they had two microlensing events, and they wanted to go public, so the MACHO team decided to go public; and as soon as OGLE detected their first event, they went public as well. Now we know that what EROS was announcing was probably not really microlensing. It just shows that people under stress claim things which don't last."

Revenge of the WIMPs

By 1995, the MACHO-versus-WIMP showdown had become incredibly volatile. In the first half of the year, the MACHO team reported that dark-halo MACHOs were few and far between, falling well below the number expected if MACHOs in the mass range to which the experiment was sensitive made up all of the dark halo. This led many people to declare WIMPs the winners. But that, too, was a premature conclusion.

"We hoped the dark halo was made more of MACHOs, because frankly it is more fun to find most of the stuff than some of the stuff," says Alcock. "But what we actually expected is that we'd see either no events or lots of events. So finding an intermediate number was very surprising."

And confusing. The MACHO team first said that 20 to 25 percent of the dark halo was made of MACHOs having the mass of brown dwarfs. Brown dwarfs



ASTRONOMY: Elisabeth Rowan

If invisible objects lurk in the Galaxy's dark halo, astronomers can detect them as they pass directly between Earth and stars in the Large Magellanic Cloud. The MACHOs act as a lens, focusing divergent light rays on Earth. This causes the background star to brighten and fade in a characteristic fashion.

range from 1 to 8 percent of the Sun's mass, not enough to spark the nuclear reactions that power ordinary stars. Such stars glow briefly, as they convert gravitational energy into heat, and then fade from view, making them ideal candidates for dark matter.

The 20 to 25 percent estimate was widely quoted, convincing many that WIMPs made up the remainder. "People tend to jump to conclusions," says Paczynski. "I just can't find any serious argument in favor of WIMPs. The interpretation of the results is very ambiguous. All you can say is that most of the dark matter is not red dwarfs and probably not brown dwarfs." He points out that MACHOs can span a wide spectrum of masses — from less than a trillionth of a solar mass up to millions of solar masses — and that the present experiments are sensitive to only a narrow section of that range. The more massive a MACHO, the longer the microlensing event lasts — which is how Alcock and his colleagues estimate MACHO masses. Low-mass MACHOs cause events lasting only a few minutes and would be missed, whereas massive MACHOs, such as black holes, cause events lasting years and would not yet have been detected.

Paczynski's skepticism proved correct. In late 1995, the tables turned yet again, this time in favor of the MACHOs. When the MACHO team analyzed additional observations, Alcock was stunned: the brown dwarf MACHOs were gone, and in their place were more massive MACHOs, clustering around 0.2 solar mass (see "A MACHO Galaxy?" AstroNews, May 1996). These MACHOs, said the scientists, constituted anywhere from 25 to 100 percent of the Milky Way's dark halo — which means there might be no WIMPs at all.

The exact nature of the MACHOs is uncertain, however. Many red dwarfs have 0.2 solar mass, but Alcock thinks that such stars would already have been seen directly if they really made up most of the dark halo. So he favors instead the idea that the MACHOs are faded white dwarfs. These burned-out remnants of solar-type stars account for 5 percent of the stars in the Galaxy's disk. As they age, white dwarfs fade and cool, so they could populate the dark halo without being seen from Earth. The trouble, though, is that the typical white dwarf — at least in our part of the Galaxy — has 0.6 solar mass, three times the mass of the MACHOs that now seem to constitute at least part of, and perhaps all of, the dark halo.

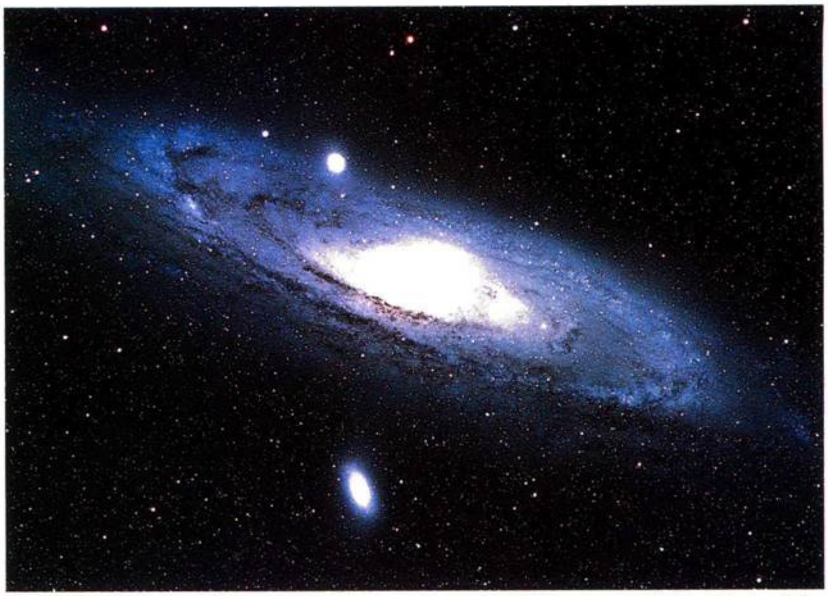
To further complicate things, there is the chance — which Paczynski thinks quite possible, Alcock very much less so — that most of the microlensing events have not been caused by objects in the Galaxy's dark halo. Instead, ordinary foreground stars in the Large Magellanic Cloud could be responsible, an idea suggested by Kailash Sahu of the Canary Islands' Institute of Astrophysics in 1994. If that is the case, then all of the Milky Way's dark matter could be WIMPs — or else MACHOs having different masses from those the experiment can now detect.

A Bright Future

With the present state of affairs so uncertain, only further observations can clarify the matter. Meanwhile, other types of MACHOs are still viable candidates. In particular, the experiments haven't been running long enough yet to detect black-hole-mass MACHOs.

"The experiment gradually becomes more and more sensitive to more massive objects as we go along," says Alcock. "But so far we have no real sensitivity to MACHOs above 10 solar masses. So if they're there, we wouldn't have seen them yet."

Other astronomers are taking aim at the Andromeda Galaxy. In 1992 Arlin Crotts of Columbia University pointed out that both Andromeda's dark halo and our own should microlens some of Andromeda's stars. In addition, Andromeda's greater distance makes it easier to detect lensing objects with as small a mass as the Moon. But Andromeda's stars are very faint due to its large distance, making the observations extremely difficult. In June, Crotts' group reported two possible microlensing events. But he says events are so rare that low-mass MACHOs – brown dwarfs and planets – appear to make up little if any of Andromeda's dark halo.



Tony and Daphne Hallas

Rather than using the Large Magellanic Cloud as a backdrop, some astronomers are looking toward the Andromeda Galaxy to search for MACHOs.

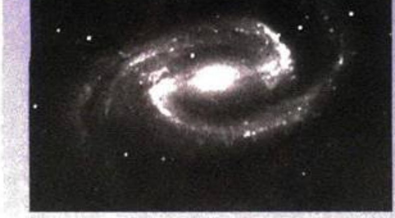
The future for the dark matter hunt is bright. "What I am optimistic about," says Paczynski, "is that within a few years, we shall cover the whole range of masses from 10^{-8} to 10^6 solar masses with a variety of microlensing experiments. And then if you don't see anything that cannot be accounted for by a few brown dwarfs here and there, I think it will probably point toward WIMPs."

For now, though, not even the scientists most closely involved in the dark matter quest know how it will come out — whether it will be all MACHOs, all WIMPs, or a mixture of both. But when the observations finally run their course, astronomers should at long last know what most of the Galaxy we call home is really made of. ☐

Ken Croswell is the author of The Alchemy of the Heavens *(Doubleday/Anchor), which is now available in paperback. The book's home page is at: http://www.ccnet.com/~galaxy.*

MACHO Men at the Galactic Bar

Although the microlensing experiments were designed to explore the Milky Way's outermost fringes, the observations have actually told astronomers a lot about its inner district, the galactic bulge. The microlensing experiments provide evidence that the bulge is elongated rather than round, which means that our Galaxy may be a barred spiral, an idea first suggested in the 1960s by Gérard de Vaucouleurs.



Yerkes Observatory

From the first, the OGLE team observed bulge stars in order to test the microlensing technique. They knew they would see microlensing as ordinary stars in the disk passed in front of bulge stars. But the astronomers got more than they bargained for: The microlensing rate toward the bulge turned out to be three times higher than they expected, and thirty times the rate toward the Large Magellanic Cloud. The MACHO team, which also observes the bulge, found a high rate of microlensing, too. Because it is so packed with stars, stars in the bulge would microlens other bulge stars at a high rate.

But the actual microlensing rate was so high that the OGLE team had to model the bulge as a bar. This bar points more or less toward us, which increases the chance that a bulge star will microlens another bulge star. This explains the greater-than-expected microlensing rate seen toward the bulge and provides evidence that our Galaxy may be a barred spiral.

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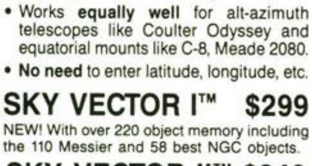

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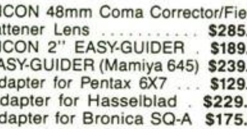

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"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain."
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Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

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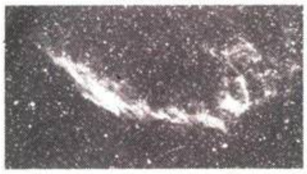
*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**



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*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

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DEEP-SKY ASTROPHOTOGRAPHY

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†U.S. Patent 4,473,636

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Specify Camera and Telescope type.

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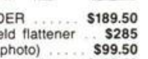

Full aperture. Installs in seconds. Specify 2" or 1¼".

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5. **LUMICON EASY-GUIDER** (selection to left) .
6. **LUMICON 48mm DEEP-SKY FILTER $119.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

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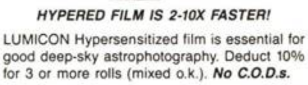

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SR-G3200, fastest of all, color neg	24	$14.95
Kodak Gold 1000 fast, fine grain	12	$13.95
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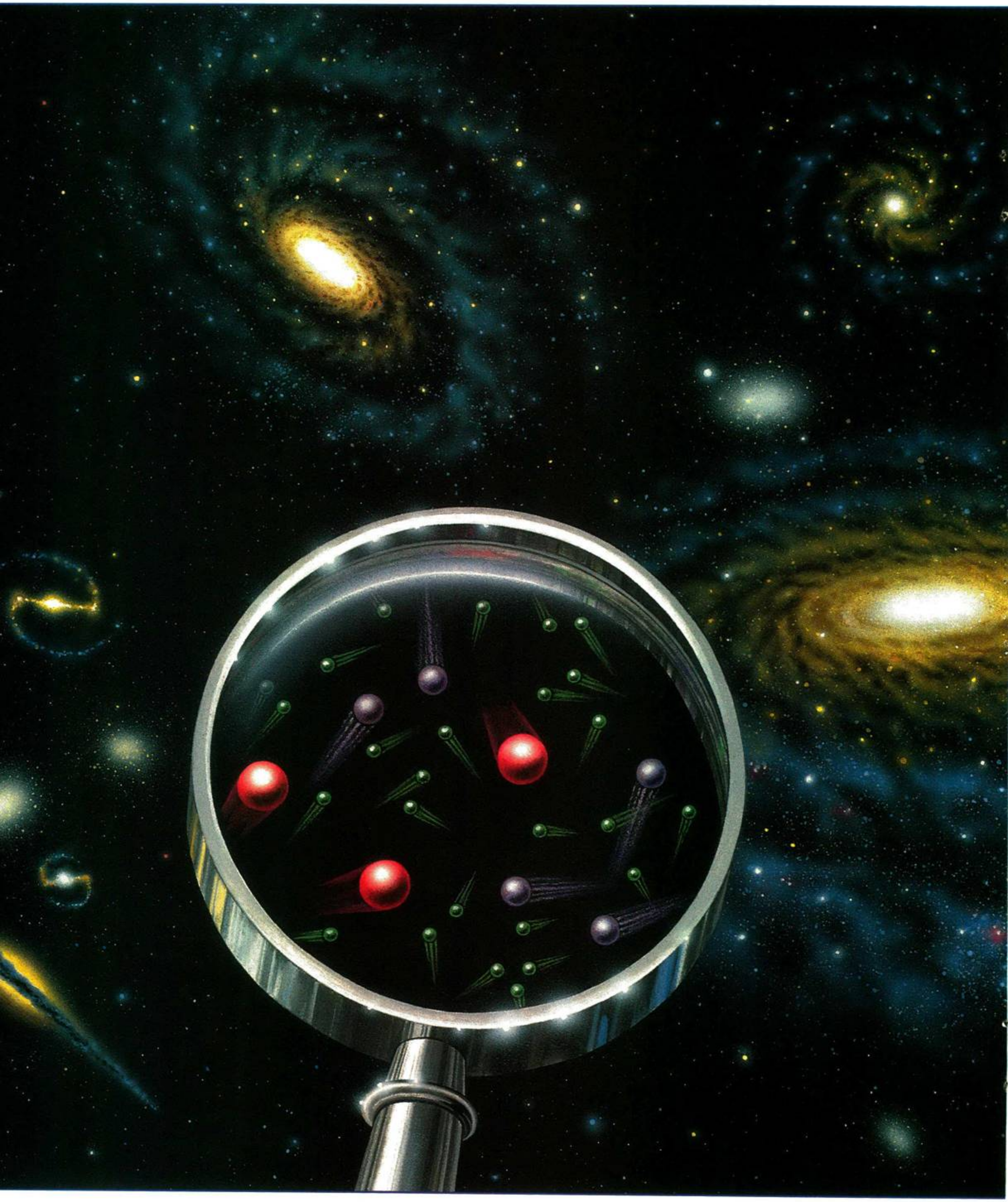
Ektachrome 1600, fast slide film	24	$14.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95



Lynette Cook

Ghosts IN THE Cosmic Machine

The answer to the dark matter mystery may lie within the murky realm of ghostly elementary particles.

by Robert Naeye

Even on the clearest night, astronomers can't see dark matter. Yet whatever it is, dark matter dominates the universe, providing far more mass than does the matter that emits light. Scientists desperately want to identify the dark matter not just because it's embarrassing not to know what the bulk of the universe is made of, but also because dark matter controls how galaxies and galaxy clusters form, and ultimately, whether the universe will expand forever or collapse back upon itself.

"Finding an answer is the number one problem in cosmology," University of London physicist Bernard Carr once said. "We're talking about 90 percent of the universe. Trying to understand the universe by observing only visible matter is like trying to describe a person having only seen their nose."

Ghostly Neutrinos

So what is this dark stuff that dominates the universe? One possibility is MACHOs, which are made up of the same protons, neutrons, and electrons that make up stars, planets, and pizza. Scientists call this atomic material "baryonic" matter.

For a second possibility, we leave the realm of celestial objects and enter the domain of elementary particles. Cosmologists find particles attractive for a number of important reasons. Most cosmologists believe the universe experienced a burst of inflation moments after its birth. If true, the universe is precariously balanced between eternal expansion and eventual collapse. But according to the big bang theory, there is more baryonic matter than astronomers have detected, but not nearly enough to bring expansion to a halt. So if inflation is correct, at least 90 percent of the universe's mass must exist in some nonbaryonic form.

Cosmologists have another reason for believing that a huge amount of nonbaryonic matter lurks undetected. Astronomers observe the cosmic microwave background — the afterglow of the Big Bang — to be remarkably smooth. There's just not enough baryonic matter to gravitationally form galaxies from such a smooth beginning.

Of the many types of elementary particles that could explain dark matter, neutrinos are the only ones known to exist. They were first predicted in 1930, and were experimentally detected in 1956. The Big Bang spewed out huge numbers of neutrinos, but nature has lots of other ways to make them too, including radioactive decay, supernovae, and nuclear reactions inside stars. Nature likes neutrinos so much that the universe contains about one billion of them for every proton or electron.

But was nature kind enough to endow neutrinos with mass, or are they massless entities like light-carrying photons? If neutrinos have no mass, they do nothing at all to solve the dark matter problem. But if they have even just the slightest smidgen of mass, their combined weight could exceed that of all baryonic matter.

Nature hasn't let the answer come easy. Neutrinos are ghostly particles that have no electric charge, and they interact rarely with baryonic matter. Billions are whizzing through your body at near light-speed as you read this sentence. But don't worry, neutrinos are so elusive that 999,999,999 out of 1,000,000,000 will plow through the entire Earth without colliding with a single particle.

A collaboration of physicists are taking up the neutrino mass challenge by using a kilometer-long particle accelerator at the Los Alamos National Laboratory in New Mexico. To bag their elusive quarry, they beam one billion neutrinos of one type every second at a pickup truck-sized tank filled with mineral oil. This past May, the group announced that over the course of about three years, 22 neutrinos of another type had registered inside the tank. The simplest explanation for this result is that one type of neutrino occasionally changed into the other type en route, an event that can only occur if neutrinos have mass.

The results are somewhat ambiguous, but they imply a neutrino mass 500 million times less than a proton. That's a tiny mass even by the standards of particle physics. But these lightweight particles are so ubiquitous that they could account for a significant chunk of the dark matter. "Neutrinos would contribute roughly the same mass to the universe as do all the stars and planets," notes Los Alamos physicist William Louis. But with the mass suggested by the Los Alamos experiment, neutrinos wouldn't provide nearly enough mass to bring expansion to a halt, meaning other forms of dark matter probably exist.

Many physicists remain cautious, noting that this result has not been independently confirmed. With more experiments soon to go on-line at Los Alamos and in England, physicists should pin down a definitive value for the neutrino mass within a few years, allowing scientists to determine how much of a dent neutrinos can put in the dark matter problem.

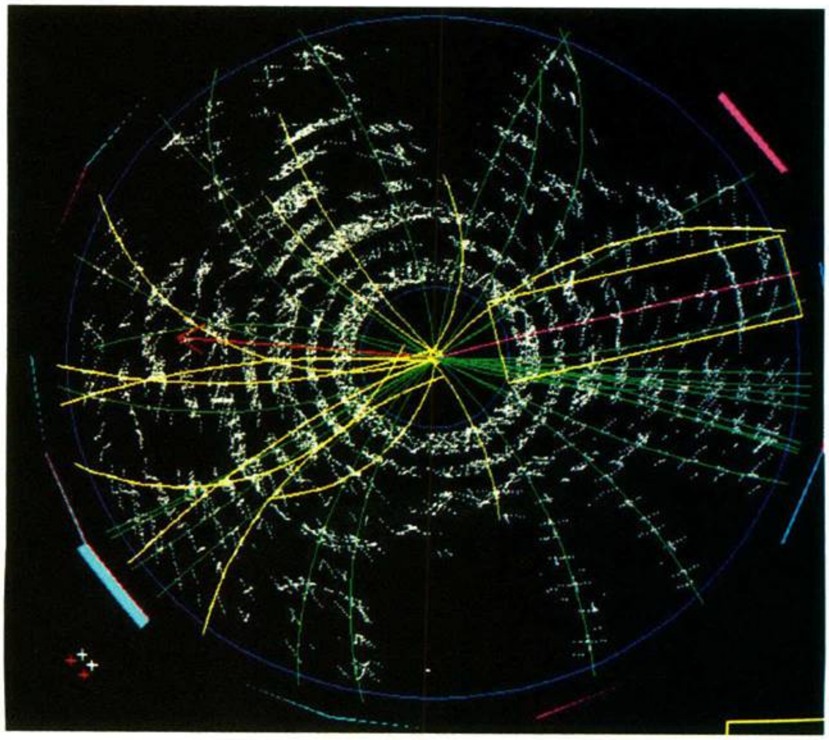
Royal Observatory, Edinburgh

WIMPs aren't so wimpy after all. Their gravitational muscle may have reigned in surrounding matter, forming galaxy clusters such as this one in Hydra.

Enter the WIMPs

If MACHOs or neutrinos don't constitute most of the dark matter, then the missing stuff must be made of something that scientists have not yet detected. When we enter the realm of hypothetical particles, WIMPs — Weakly Interacting Massive Particles — are attractive candidates because they emerge naturally from particle theories that evoke "supersymmetry," in which each type of familiar subatomic particle has a "supersymmetric partner." Physicists are fond of supersymmetry theories because they seem to be a necessary step in the unification of all nature's forces.

If you thought neutrinos were elusive, WIMPs are even more so. Supersymmetry says that WIMPs will barely interact with baryonic matter except through gravity. The heaviest WIMPs congealed in large numbers shortly after the Big Bang, but they quickly decayed into lighter WIMPs. Only the



Fermilab

Tiny particles leave behind telltale tracks inside a detector at the Fermilab particle accelerator in Illinois. WIMPs might turn up in one of these experiments.

Lawrence Livermore National Laboratory

Scientists at the Lawrence Livermore National Laboratory in California are hoping to catch axions – the particle named after a laundry whitener – as they pass through a superpowerful magnet (right).

wimpiest of the WIMPs are still around today. But even these are beefy little particles. Compared to the lightweight neutrinos, which are much less massive than protons, WIMPs are veritable heavyweights, weighing in with a mass 10 to 100 times that of protons. Thus the particle with the less-than-desirable acronym could easily be master of the universe.

Many cosmologists are rooting for WIMPs because WIMPs can explain how the smooth Big Bang evolved into the lumpy galaxy-laden cosmos we see today. Because they're heavy, WIMPs move much slower than light. Gravity enables the slow-moving WIMPs to clump together into enormous clouds. These clouds could have acted as the gravitational "seeds" that reigned in baryonic matter, forming galactic-scale structures.

If this picture is correct, the entire Milky Way Galaxy is embedded in a vast cloud of WIMPs. As the solar system orbits the galactic center, the Earth plows through this cloud at 220 kilometers per second. Physicists hope to detect WIMPs as they zoom by.

The leading American WIMP-hunting group, which has just begun its experiment, is being led by physicists at Stanford University and the University of California at Berkeley and Santa Barbara. The group chills ultrapure germanium and silicon crystals to .02° C. above absolute zero. To shield the crystals from the effects of cosmic rays, the experimentalists store them three stories below the surface at the Stanford Underground Facility. Once every week at most, one out of the hundred trillion WIMPs that may pass through the crystals would interact with an atom in the crystal lattice, heating the crystal by a few millionths of a degree and knocking a few electrons loose. Groups in England, Germany, and Japan are also searching for WIMPs using different methods. "Our experiments will either find evidence for WIMPs or make these particles much less attractive candidates for the dark matter," says Stanford physicist Blas Cabrera.

Some physicists think WIMPs have already turned up in particle accelerator experiments at Fermilab in Illinois and the European Center for Nuclear Research (CERN) in Switzerland. These high-energy experiments recreate conditions that existed moments after the Big Bang, so if a particle turns up in these experiments, chances are that it exists in nature too.

University of Michigan physicist Gordon Kane points to one particular interaction seen at Fermilab in April 1995 that looks exactly like a heavy WIMP decaying into a lighter WIMP. "This conclusion is not as secure as one would like because only one event

Particle	Relative Mass
Proton	1.000
Neutron	1.001
Electron	0.0005
Neutrino	~0.000000002
WIMP	~40
Axion	~0.00000000000001

shows this decay directly, but it is a clean and dramatic event," says Kane. The purported WIMP appears to be about 40 times more massive than a proton. When Kane takes this mass and multiplies it by the particle's predicted cosmic abundance, he winds up with just the right total mass to keep the universe balanced between eternal expansion and collapse, which supports the idea of inflation.

Fermilab cosmologist Rocky Kolb cautions, "Gordy's interpretation makes as much sense as any other interpretation, but not many people are going to believe it based on one event." With Fermilab and CERN being upgraded, both Kane and Kolb agree that WIMPs will be discovered or ruled out within the next few years. If WIMPs exist, Fermilab, CERN, and the specialized WIMP detectors are racing to see who can make the first definitive detection.

Cosmic Featherweights

And then there are axions, the particle named after a laundry whitener. If WIMPs are heavyweights and neutrinos are lightweights, axions are featherweights. If axions exist, each of these ethereal particles would weigh in with a mass less than one-trillionth that of a proton. And like neutrinos and WIMPs, axions would have almost complete disdain for baryonic matter.

Physicists first conceived of axions 20 years ago to explain certain unusual properties of the neutron. According to theory, axions were created moments after the Big Bang. There could be 100 trillion packed into each cubic centimeter of space, meaning these wimpier-than-WIMP particles would be the dominant form of matter in the universe if they exist.

To search for axions, scientists at the Lawrence Livermore National Laboratory in California installed a tunable microwave cavity inside an automobile-sized magnet that generates a field 150,000 times stronger than Earth's. The axion hunters continually tune the cavity, just as one would tune a radio. When the cavity is tuned to the right frequency, axions passing through the detector will decay into microwaves. State-of-the-art amplifiers "listen" for the faint microwave signal. The cavity itself is cooled to just 1.5° C. above absolute zero in order to prevent heat from the experimental apparatus from masking the impact of an axion. This experiment, along with a similar one at Kyoto University in Japan, has just begun operation. "I think it will probably take a decade to answer the question of whether axions exist," says University of Florida physicist Pierre Sikivie, who works with the Livermore group.

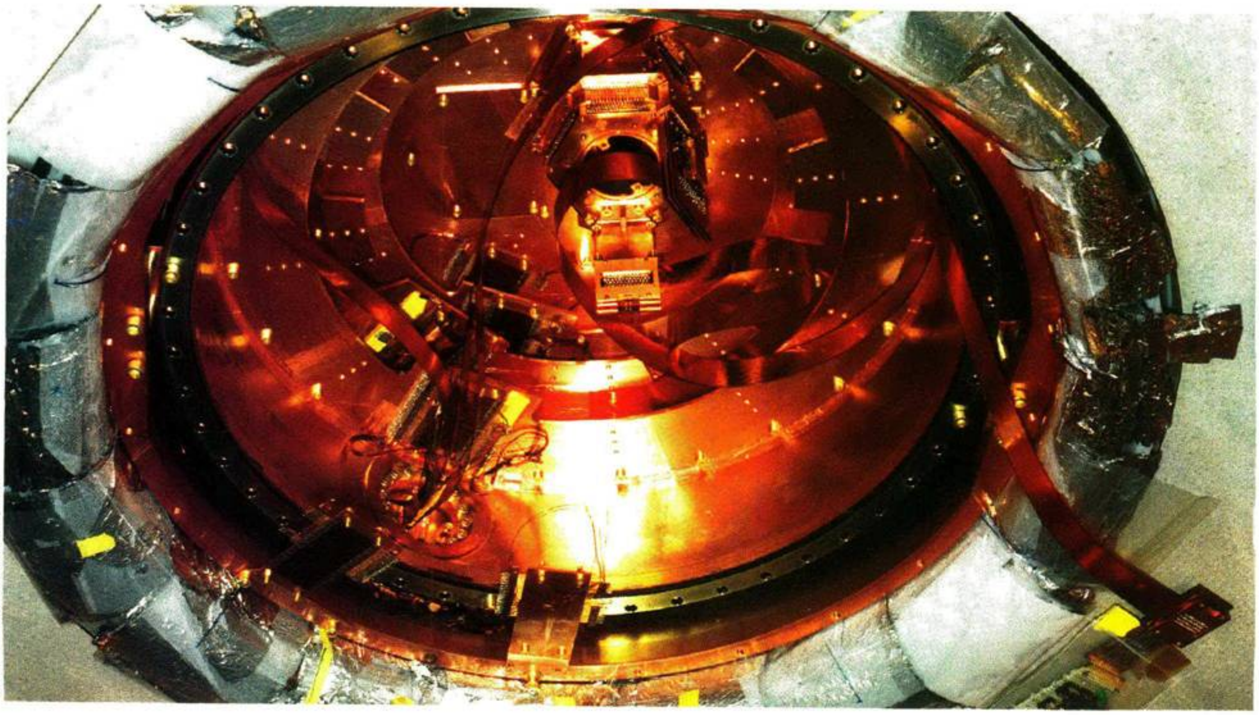
Is Something Else Wrong?

A small number of scientists argue that dark matter doesn't exist at all; they think that something else is pulling off a cosmic sleight-of-hand. They have proposed a number of possibilities that, if true, could alter our current concepts of the universe so thoroughly that the dark matter problem might vanish.

One possibility is that there is an additional force represented by the "cosmological constant," a term Albert Einstein inserted into his basic equations when he thought the universe was static. Einstein later discarded the cosmological constant when the universe was found to be expanding.

But some physicists are trying to resurrect the cosmological constant. A cosmological constant makes "vacuum energy" reside in apparently empty space. As the universe expands, new space

A California-based group chills ultrapure germanium and silicon crystals inside this cavity to .02 kelvins. A few WIMPs that pass through the detectors will interact with atoms in the crystals.



Center for Particle Astrophysics

appears, and it too possesses vacuum energy. So the universe gains energy simply from its ongoing existence — the ultimate free lunch. Since Einstein's famous *equation* E = mc^2 showed that energy and mass are equivalent, this additional energy appears to act like invisible mass.

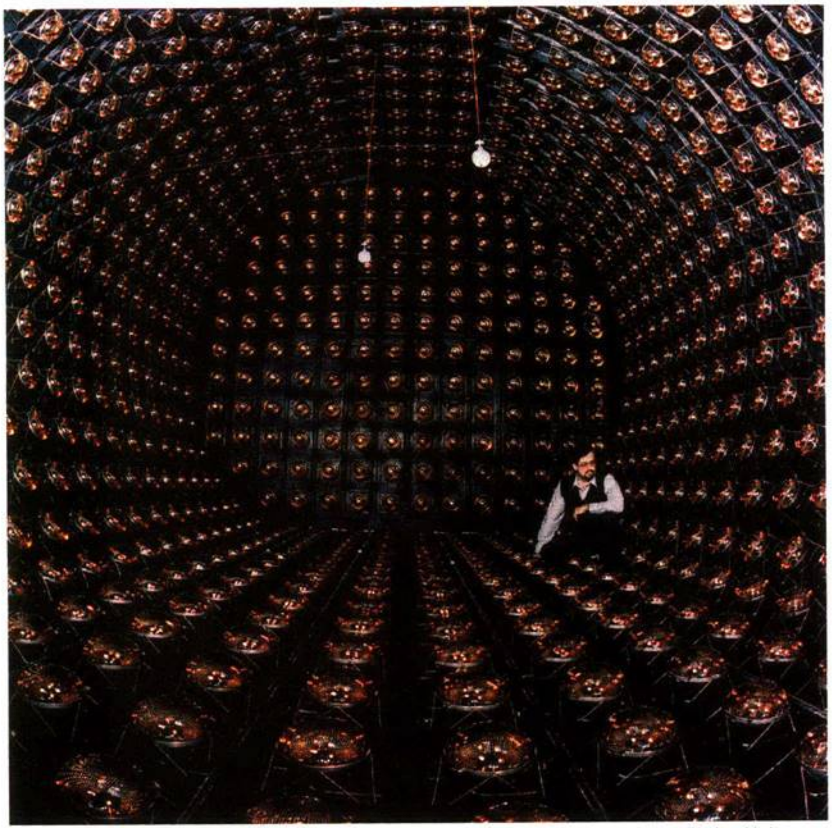
To get the universe we see, in which there is 10 to 100 times more dark matter than visible matter, some theorists have adopted a cosmological constant. But to many astronomers, this is an aesthetically displeasing solution. Furthermore, attempts to directly observe the effects of a cosmological constant have come up empty, meaning it probably doesn't exist, or its effects are too small to have much of an impact on the dark matter problem.

A few scientists argue that our understanding of gravity on large scales is flawed. After all, Einstein's theory of gravitation superseded Newton's. Will Einstein's someday be superseded?

New theories have been suggested, and one of them might prove correct. But nobody has ever proposed a compelling explanation for why Einstein's theory of gravity would fail at large scales. Moreover, astronomers have two independent methods for measuring the gravitational force in large-scale structures such as galaxy clusters. First, they measure the motions of galaxies within the cluster. Second, they can measure how much a cluster bends light from more distant objects. These two independent methods always yield the same answer, strongly supporting the view that our understanding of gravity does indeed work on large scales as well as small.

Physicists have dreamed up many other possible solutions to the dark matter problem. Some involve new particles or forms of matter, such as shadow matter, cosmic strings, quark nuggets, gravitons, monopoles, and mini-black holes. Others question our theories of motion and time.

But for now, most scientists are content to stick with MACHOs, neutrinos, axions, and supersymmetric WIMPs. "They are the most popular candidates because they seem to require a smaller step away from the physics that we do know," says Kolb. "We know enough about their properties to search for them in the laboratory. It's much more attractive to come up with a candidate that can be tested than one that you don't have any idea how to test."



Los Alamos National Laboratory

To find out if neutrinos have mass, physicists at the Los Alamos National Laboratory in New Mexico fill this tank with mineral oil and bombard it with one billion neutrinos every second. Early results suggest that neutrinos have a small yet significant mass.

The Answer?

So what will the answer be? Opinion is divided. Many astronomers are putting their money on MACHOs. Some particle physicists, like Gordon Kane, are betting on a mix of particles. "It will be a combination of WIMPs and massive neutrinos," he predicts. "I don't see how it can't be that, because they work so well theoretically and they fit with what astronomers need."

Rocky Kolb, on the other hand, thinks it will be just one thing. "Everyone is going to mixed models, but it's hard to imagine that nature maximizes theoretical jawing in such a way that a lot of different ideas are correct."

But the fact that scientists are involved in such a discussion demonstrates how much progress is being made. Just six decades ago, nobody even knew that a dark matter problem existed. Now, with MACHO searches well underway and neutrino, WIMP, and axion experiments moving into high gear, we probably won't have to wait much longer for the answer.

Because dark matter ultimately controls the universe, whatever the resolution to the great cosmic dark matter mystery turns out to be, will, in turn, help solve other profound cosmological conundrums. So even though this mystery has stymied scientists for decades, they can be thankful for dark matter, since it will ultimately lead to a much deeper understanding of the universe. ☐

ASTRONOMY associate editor Robert Naeye (rnaeye@astronomy. com) is rooting for the WIMPs.

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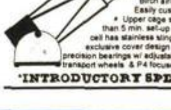

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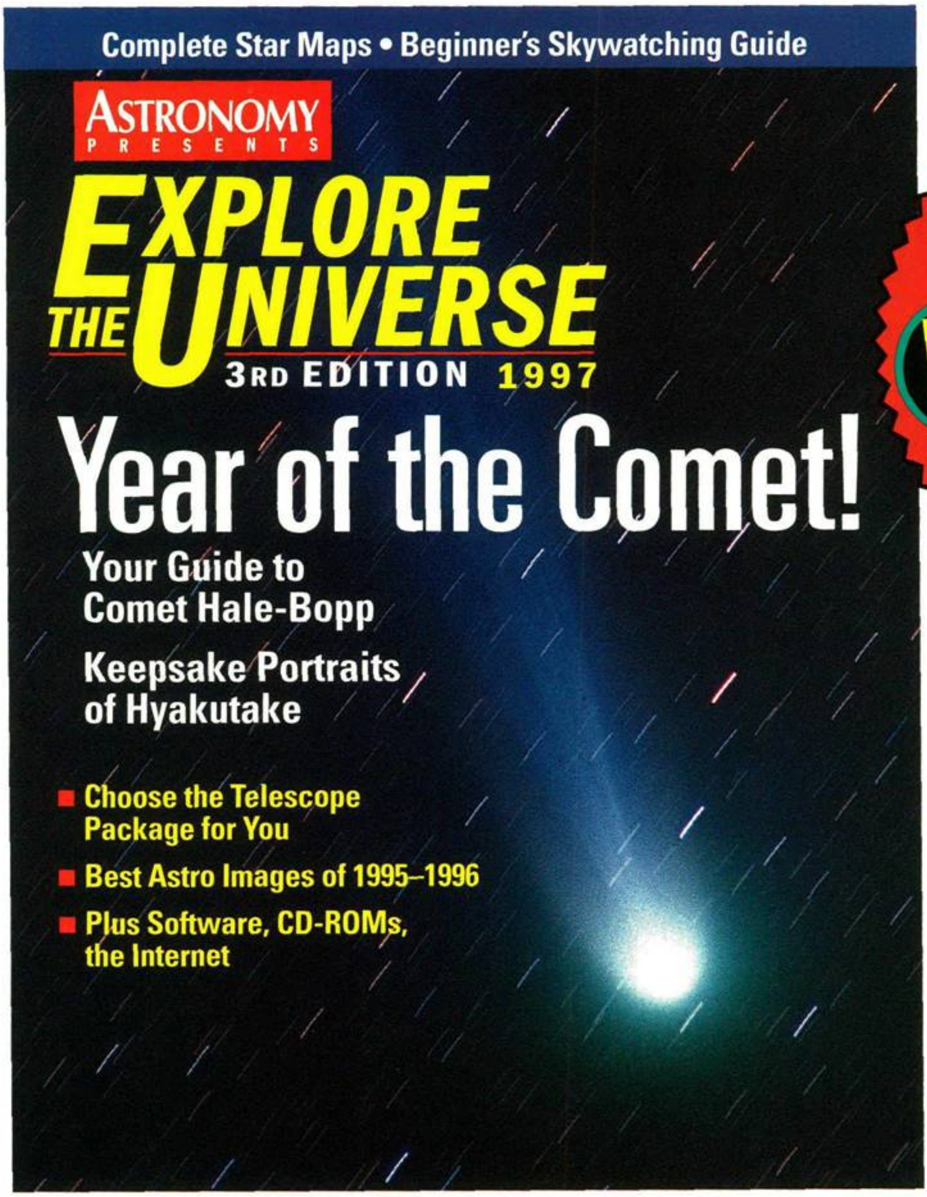

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SKY ALMANAC

Nightfall reveals the Gas Giant planets Jupiter, Uranus, Neptune, and Saturn huddled above the horizon. Higher up, a lengendary snake tamer shelters next spring's great comet, Hale-Bopp.

by Martin Ratcliffe

Highlights
by Rick Shaffer

Date .... Event
10 Morning's Arrow to the Sun ....(p. 66)
18 Luna Salutes Jupiter & Hale-Bopp ..(p. 67)
21 Year of the Orionids ......(p. 65)
28 The Moon in a Bull's Eye .....(p. 67)

all month:
First Views:
Fall's Really Big Nebula ...(p. 63)
Observer's Challenge:
NGC 7331's Galactic Companions ....(p. 64)
October's Ethereal Zodiacal Light ..(p. 65)
Juno the Night Away ....(p. 66)

Crisp, clear evenings and falling nighttime temperatures are the hallmarks of October evenings. As lingering twilight echoes the color of autumn leaves, a brilliant object lies due south, the first celestial gem to call attention to itself.

It is magnitude –2.2 **Jupiter**. An hour or so after sunset the star clouds of Sagittarius appear to gather around the giant planet, which stands 25° above the southern horizon at around 6 p.m. local time.

Some interesting alignments involve Jupiter during October. First of all, on October 1 Jupiter, Earth, and the Sun form a right angle to one another.

This line-up marks the moment when Jupiter reaches what's called eastern quadrature, when the mighty planet sets around midnight local time (1 a.m. daylight saving time).

Three weeks later, Jupiter and Mars lie at heliocentric opposition, when the duo lie on opposite sides of the Sun. Because Jupiter is an evening object, a little geometry tells us we won't see the Red Planet until the early morning hours during October.

After taking some time to study Jupiter's clouds and moons through a telescope, don't forget two other gas giant worlds lurk nearby. **Uranus** and **Neptune** lie within 20° or so of Jupiter.

As a guide to finding them, the waxing first quarter Moon glides past Jupiter, Neptune, and Uranus between October 18 and 20. It's closest to Uranus and Neptune on October 19.

Neptune's tiny 8th-magnitude bluish disk rests 15° east of Jupiter and can be found using a scope, while Uranus, two magnitudes brighter and 6° farther east, is easy in binoculars.

One final gas giant planet, **Saturn**, mounts the east an hour after sunset to stand about 20° above the horizon. By midnight it glows due south in southern Pisces, offering a fine opportunity for you to glimpse its barely open ring system.

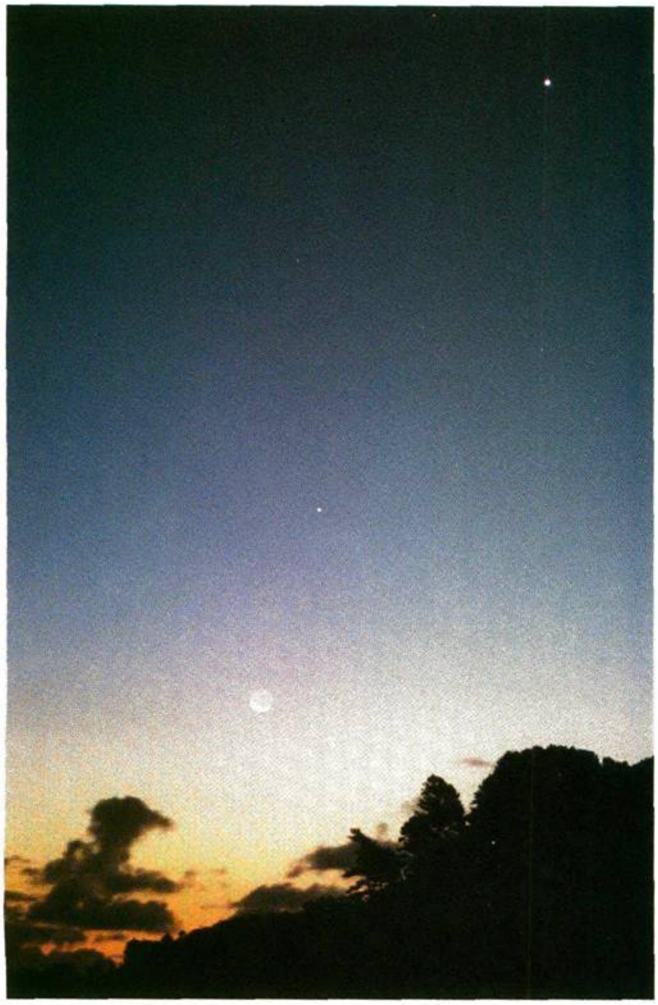
Saturn is just past opposition and has dimmed slightly this month to magnitude 0.6.

As the Ringed Planet climbs higher in the sky through evening, the heavens also keep pace. The gentle spin of Earth causes Arcturus to set in the northwest as Saturn clears haze on the opposite horizon.

Swinging under Polaris, the Big Dipper's handle tracks the descent of orange Arcturus and its companion stars of spring as they bid farewell until next year.

East of Bootes the Herdsman is the celestial crown of Corona Borealis, while still farther to the east rides Hercules the legendary strongman, which sets by midnight.

Mighty Hercules bumps heads with another blue-collar muscleman, Ophiuchus the Serpent Holder. On October evenings he stands low in the southwest after sunset, arms firmly in control of the serpent's front



Joe Myers

Nothing quite matches the sight of a waning crescent Moon and brilliant Venus. October 10's morning conjunction looks very much like this one taken in 1992.

1996

OCTOBER

1 The Moon passes 0.8° north of Aldebaran, 6 p.m. EDT

3 Mercury is at greatest western elongation (18°), 2 a.m. EDT
Venus passes 0.2° south of Regulus, 8 p.m. EDT

4 Last quarter Moon is at 8:04 a.m. EDT
Asteroid Juno is at opposition (page 66)

6 The Moon is at apogee (404,791 kilometers from Earth), 1:54 p.m. EDT

7 The Moon passes 6° south of Mars, 11 a.m. EDT

8 The Moon passes 4° south of Venus, midnight EDT

12 New Moon is at 10:14 a.m. EDT; partial solar eclipse

18 The Moon passes 6° north of Jupiter, noon EDT

19 The Moon passes 5° north of Neptune, 1 p.m. EDT
First quarter Moon is at 2:09 p.m. EDT
The Moon passes 6° north of Uranus, 11 p.m. EDT

21 Orionid meteor shower peaks (page 65)

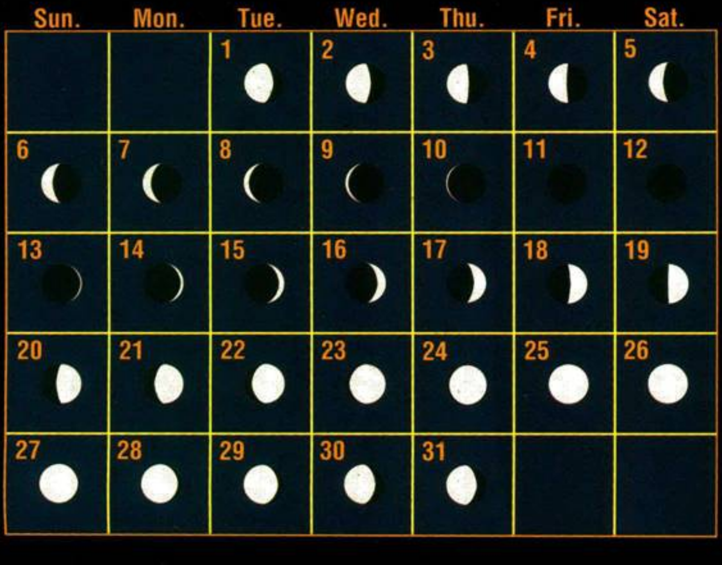
22 The Moon is at perigee (368,350 kilometers from Earth), 4:46 a.m. EDT

24 The Moon passes 3° north of Saturn, 6 a.m. EDT

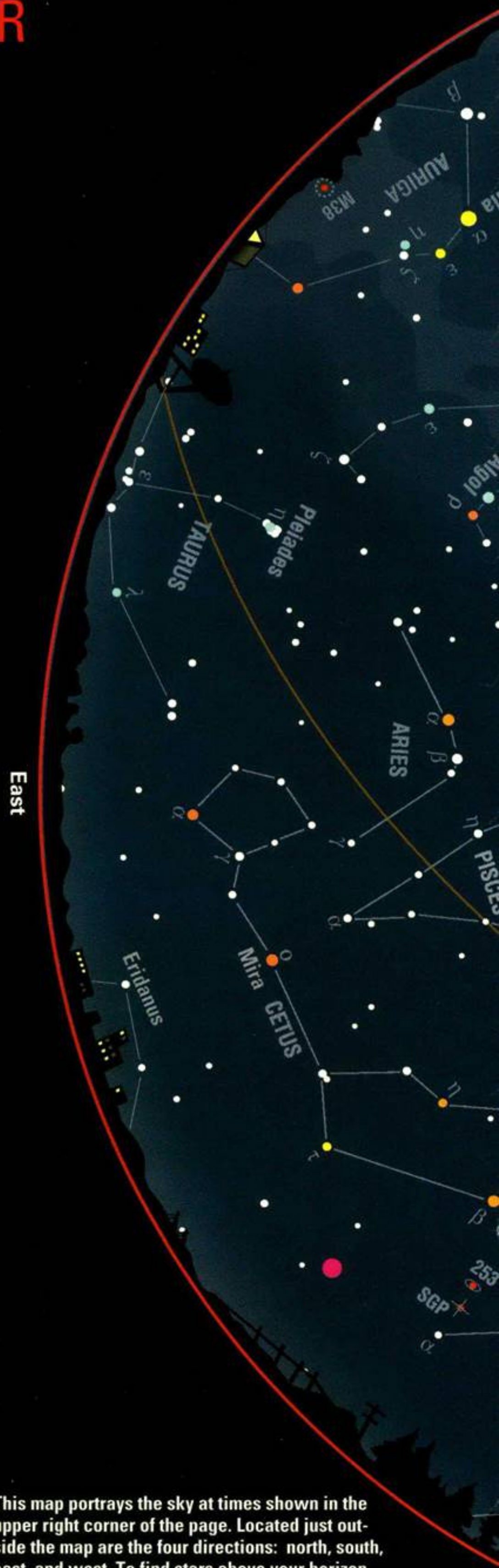
26 Full Moon is at 10:11 a.m. EDT

28 Mars passes 1.2° north of Regulus, 11 p.m. EST

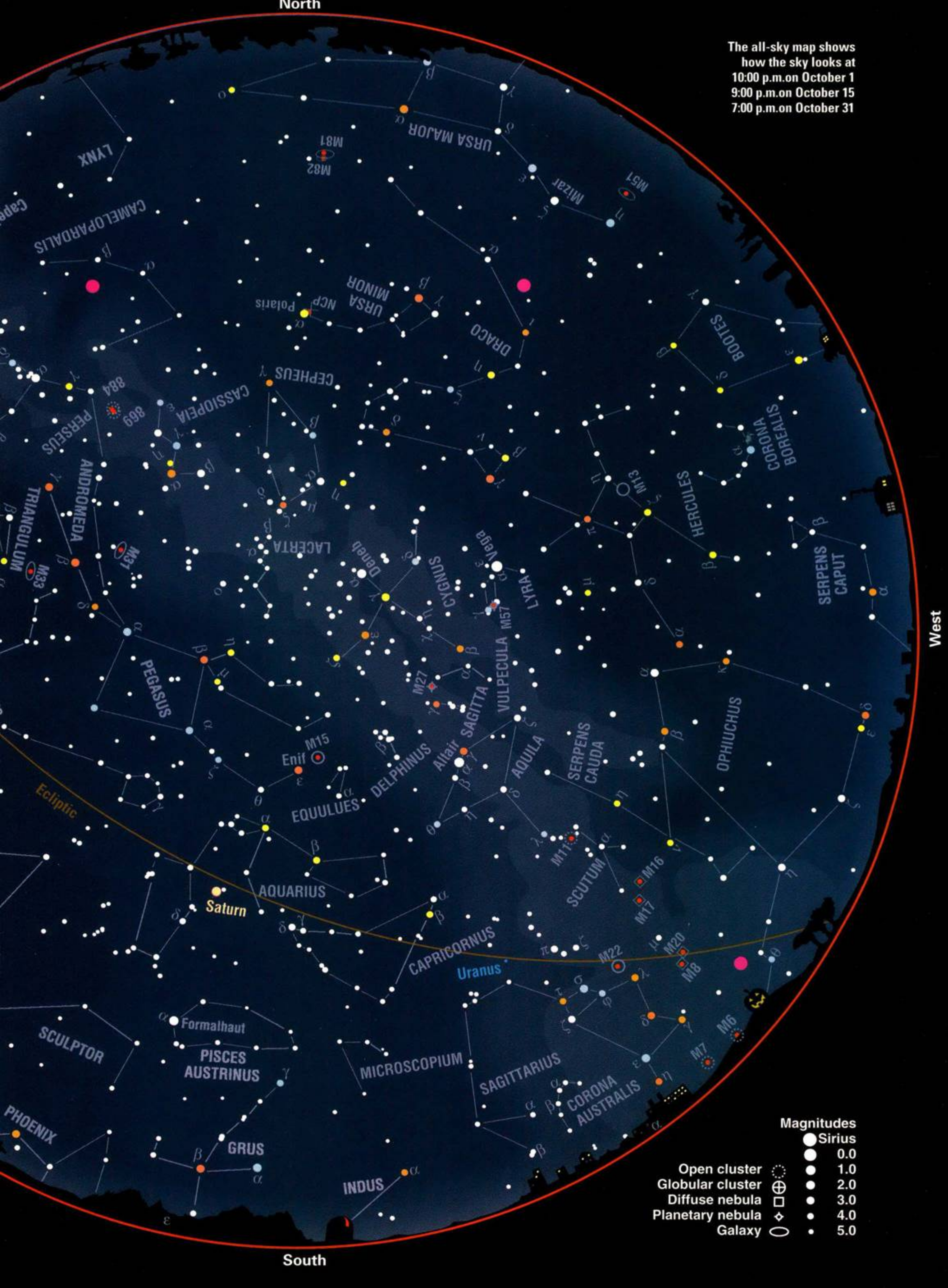
29 The Moon passes 0.9° north of Aldebaran, 3 a.m. EST



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

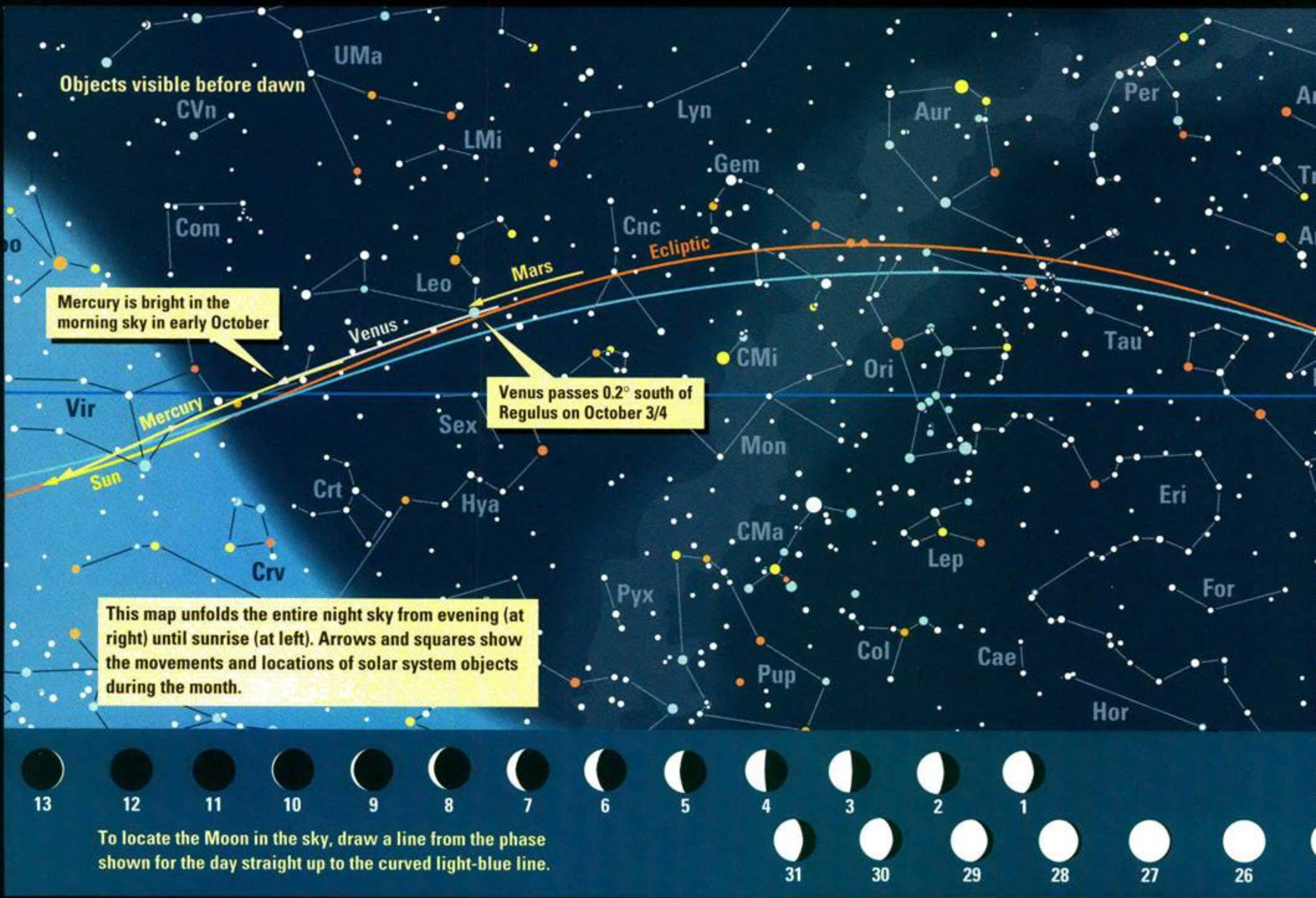


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
West
South
LYNX
URSA MAJOR
M81
M82
Mizar
M51
CAMELOPARDALIS
URSA MINOR
NCP
Polaris
DRACO
BOOTES
CEPHEUS
CASSIOPEIA
PERSEUS
884
869
CORONA BOREALIS
M13
HERCULES
ANDROMEDA
TRIANGULUM
M33
M31
LACERTA
Deneb
CYGNUS
Vega
LYRA
M57
SERPENS CAPUT
VULPECULA
M27
SAGITTA
PEGASUS
OPHIUCHUS
Enif
M15
DELPHINUS
Altair
AQUILA
SERPENS CAUDA
EQUULEUS
Ecliptic
M11
SCUTUM
M16
M17
AQUARIUS
Saturn
CAPRICORNUS
Uranus
M22
M20
M8
M6
M7
Formalhaut
SCULPTOR
PISCES AUSTRINUS
MICROSCOPIUM
SAGITTARIUS
CORONA AUSTRALIS
PHOENIX
GRUS
INDUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
10:00 p.m.on October 1
9:00 p.m.on October 15
7:00 p.m.on October 31

THE PATH OF THE PLANETS

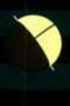

Objects visible before dawn
UMa
CVn
LMi
Lyn
Aur
Per
Gem
Com
Cnc
Ecliptic
Leo
Mars
Venus
Mercury
Sun
Vir
Sex
CMi
Ori
Tau
Mon
Crt
Hya
Eri
CMa
Lep
Crv
Pyx
For
Col
Cae
Pup
Hor
13
12
11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27
26

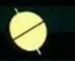
Mercury is bright in the morning sky in early October

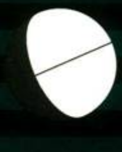
Venus passes 0.2° south of Regulus on October 3/4

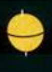
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.



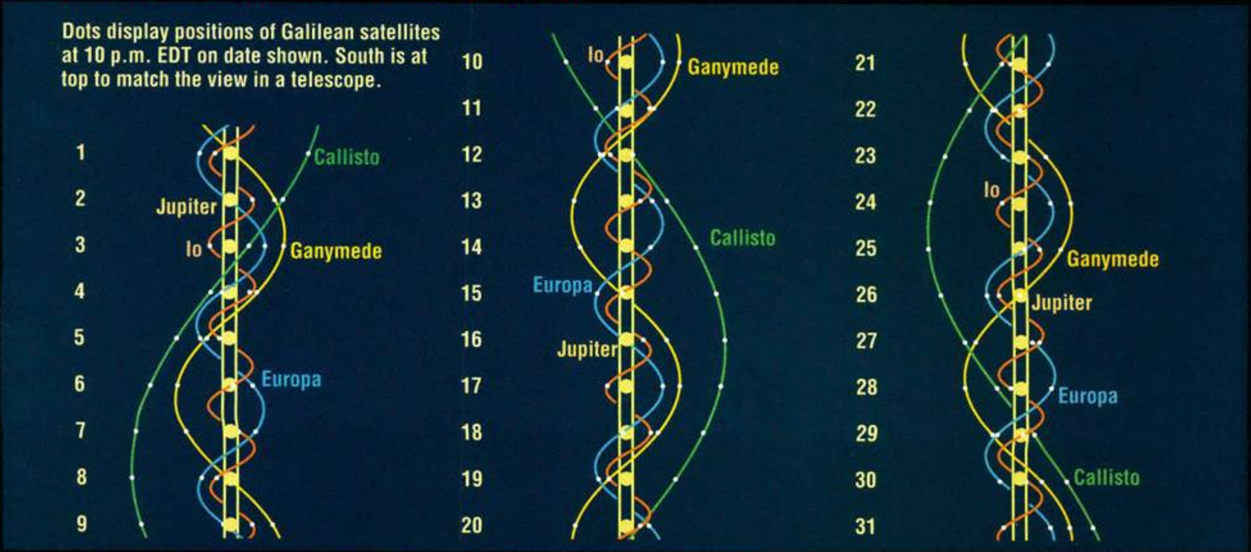




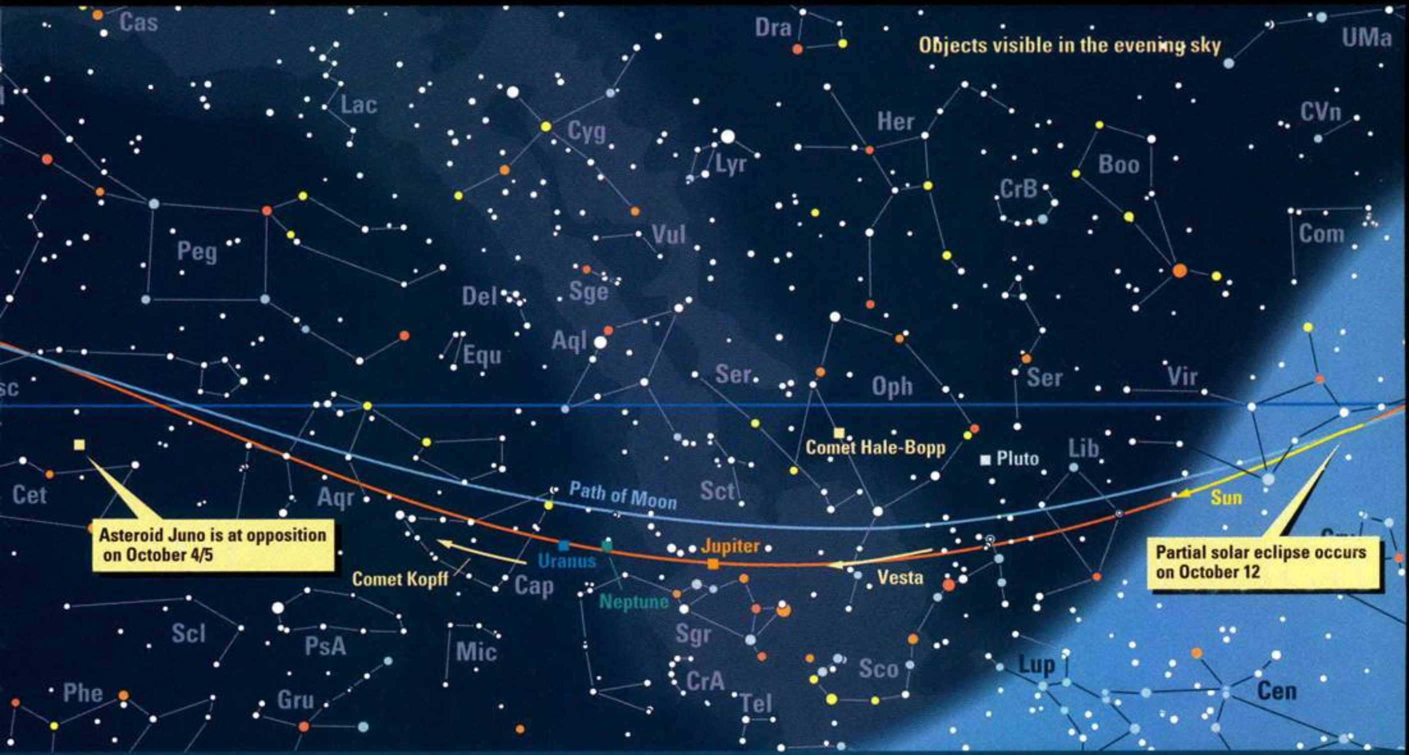


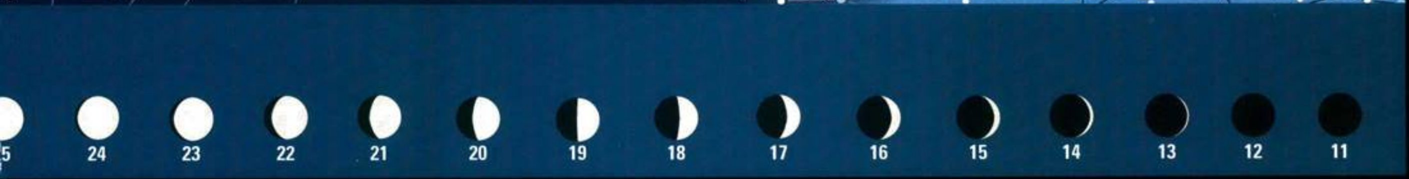
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPIT
Date	October 1	October 15	October 15	October 15	Octobe
Magnitude	–0.1	–1.0	–4.1	1.4	–2.2
Angular Size	7.5″	5.4″	14.9″	5.1″	37.4
Illumination	41%	89%	74%	92%	99%
Distance (AU) from Earth	0.897	1.249	1.118	1.847	5.27
Distance (AU) from Sun	0.308	0.351	0.719	1.612	5.16
Right Ascension (2000.0)	11h26.7m	12h38.1m	10h57.8m	9h36.8m	18h45.
Declination (2000.0)	4°33′	–2°01′	7°37′	15°42′	–23°1

JUPITER'S MOONS



Dots display positions of Galilean satellites at 10 p.m. EDT on date shown. South is at top to match the view in a telescope.


Cas
Dra
Objects visible in the evening sky
UMa
Lac
Cyg
Lyr
Her
CVn
Boo
CrB
Peg
Vul
Com
Del
Sge
Aql
Equ
Ser
Oph
Ser
Vir
Comet Hale-Bopp
Pluto
Lib
Cet
Aqr
Path of Moon
Sct
Sun
Asteroid Juno is at opposition on October 4/5
Jupiter
Uranus
Comet Kopff
Cap
Neptune
Vesta
Partial solar eclipse occurs on October 12
Scl
PsA
Mic
Sgr
Sco
Lup
Cen
Phe
Gru
CrA
Tel


24
23
22
21
20
19
18
17
16
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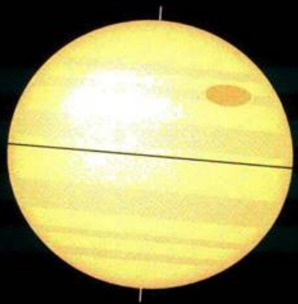
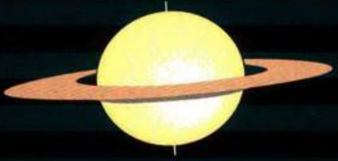
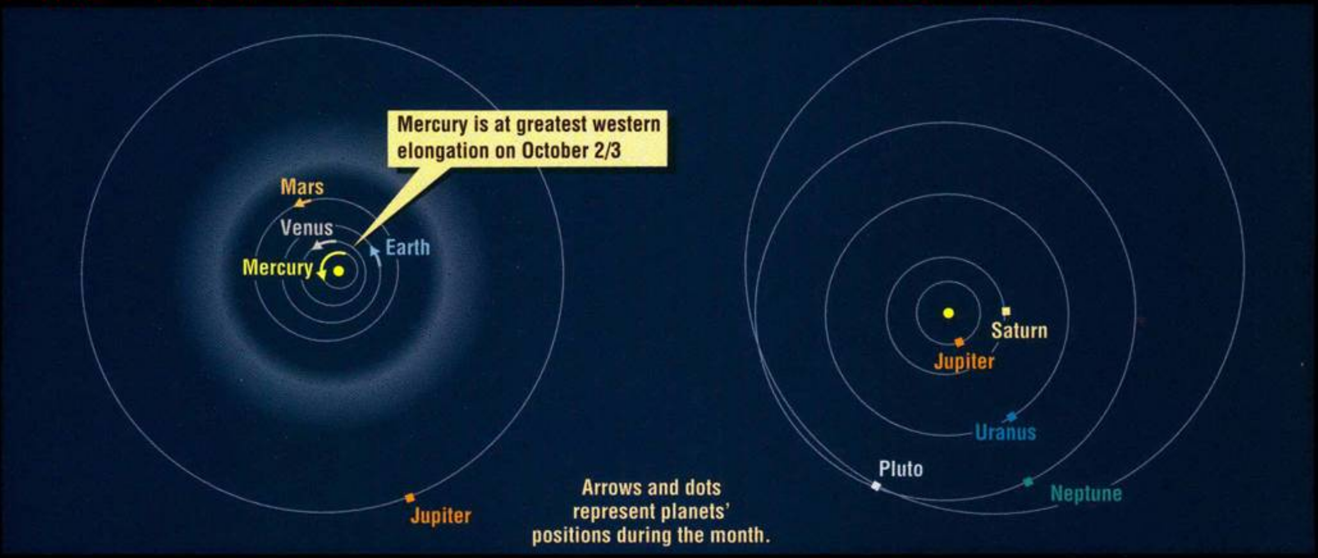
14
13
12
11





	SATURN	URANUS	NEPTUNE	PLUTO
15	October 15	October 15	October 15	October 15
	0.6	5.8	7.9	13.8
	19.4″	3.6″	2.3″	0.1″
	100%	100%	100%	100%
	8.548	19.611	30.088	30.675
	9.494	19.787	30.158	29.932
	0h13.8m	20h12.2m	19h47.6m	16h07.8m
	–1°21′	–20°35′	–20°41′	–8°12′

THE PLANETS IN THEIR ORBITS


Mercury is at greatest western elongation on October 2/3
Mars
Venus
Earth
Mercury
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Arrows and dots represent planets' positions during the month.

(Serpens Caput) and back (Serpens Cauda).

Ophiuchus also holds **Comet Hale-Bopp** within its embrace this month. The comet moves slowly northeast and is now an easy binocular object, perhaps visible to the naked eye if your skies are very dark.

On October 28 Hale-Bopp picks up a companion when it reposes less than ⅓° west of the magnitude-7.5 globular cluster M14. This affords a fine photographic opportunity, one of many that will be forthcoming during the comet's long-awaited apparition.

Hale-Bopp's motion through the sky is drawing a bead on the Summer Triangle of Deneb, Vega and Altair. These three bright stars, among the sky's brightest, shine like beacons embedded in the summer Milky Way, high up on the sky's dome.

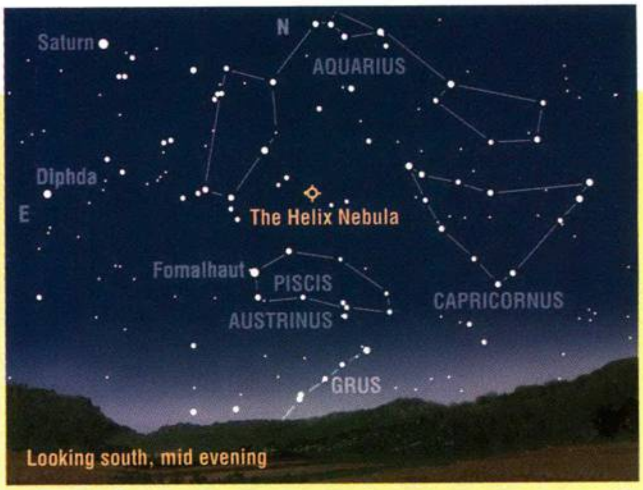
Hale-Bopp cleaves their triangular arrangement in the predawn sky, low above the eastern horizon, during February and March.

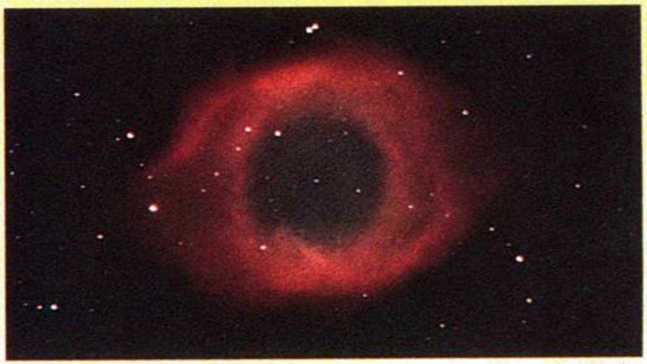
Tonight, though, the Milky Way surrounding the Triangle holds our attention. Its soft glow swings from a north-south direction to an east-west direction during the six hours after sunset.

As evening progresses, watch its splashiness yield to the dimmer fall constellations starting their march across the sky.

Aquarius the Water Bearer leads the way with Pegasus galloping close

First Views:
Fall's Really Big Nebula





Jack Marling

Despite it being my birth "sign," Aquarius has always been a ho-hum constellation for me. Try as I might, I can't visualize in its stars a mythological character bearing water. Aquarius the Water Bearer, however, makes up for its lacklusterness by harboring several exquisite deep-sky objects.

The bright globular star cluster M2 and the unusually shaped planetary nebula dubbed the "Saturn" Nebula, NGC 7009, are the best known deep-sky objects in Aquarius. But, for the most lasting impression, nothing beats the Helical Nebula, NGC 7293.

The Helix, as it's often called, is the closest and biggest planetary nebula. Objects like these are ghostly spherical shells of gas "sloughed off" the outer regions of an unstable star. The Helix is about 500 light-years distant, making it about 1.7 light-years across. The central star in it and in other typical planetary nebulae is usually an extremely hot blue dwarf whose diameter is only a few percent of our Sun.

Since it's extremely hot, the 13.5-magnitude central star that powers the Helix emits copious amounts of ultraviolet light. This radiation causes the surrounding gas shell to fluoresce, just as the tube of my desk lamp does. Our eyes are most sensitive to the greenish light of doubly ionized oxygen, so we mostly see planetaries as greenish, although this photo of the Helix to the right shows there's a lot of red as well.

In spite of your eye's green sensitivity, you are not likely to visually detect any color in the Helix. That's because the Helix's size spreads its brightness out over an area of 10'x12', slightly less than half the size of a Full Moon. This makes it look very dim and colorless.

Since the Helix's surface brightness is at or below the average brightness of the background sky for many locations, to boost your chances of seeing it, pick a night as dry and still as possible. Most importantly, observe from as dark a location as possible, far away from city lights.

The best Helix-hunting instrument is a pair of 10x70 binoculars. Their 5° field of view yields plenty of dark sky around the nebula and allows room to pan back and forth across the Helix's position, an important search tactic.

Since we evolved from ancestors who successfully avoided night predators, our eye/brain combination sees big, dim, moving objects much better than big, dim, stationary ones.

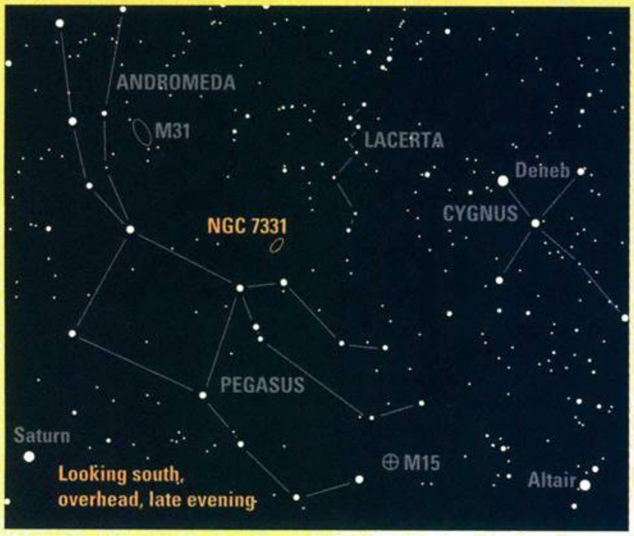
Making the sky move relative to your view makes the big, dim, Helix pop into view easier. Once you find it, the nebula will be quite easy to see without moving the binoculars.

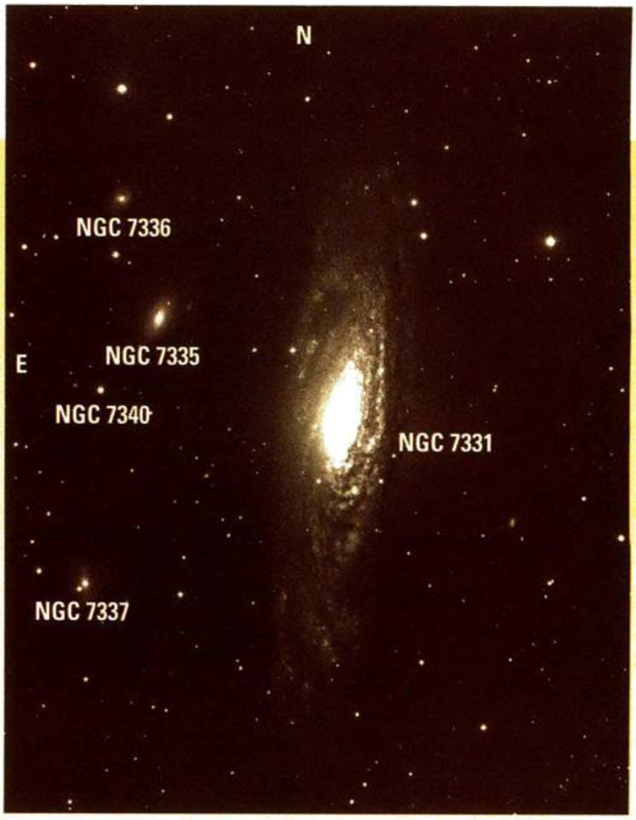
Seeing the Helix in a telescope requires very low power. Again, work at a wide enough field to include some dark sky around the nebula.

I've found that a 6- to 10-inch scope operating at 21x to 35x works well on this object. Moving the telescope back and forth across the field of view, while harder than with binoculars, is still a useful technique in finding the Helix. — *Rick Shaffer*

Observer's Challenge:

NGC 7331's Galactic Companions





Mt. Wilson Observatory

Pegasus harbors a host of galaxies for our observing pleasure. However, we often settle on flashier M31 and M33 in neighboring Andromeda and Triangulum to the exclusion of dimmer objects under the wings of the horse.

One of those objects is NGC 7331, a magnitude-9.5, nearly edge-on galaxy often used as a starting point in the hop to Stephan's Quintet, a rather attractive galaxy cluster some 3° to the southwest. This is too bad, for NGC 7331 itself is a worthy target, not to mention its galactic companions that linger nearby.

But first, NGC 7331.

If it weren't about twenty times farther than M31, this galaxy would easily rival the Andromeda Galaxy. It has dust lanes visible in 16- to 24-inch telescopes, as well as rich star-formation regions. The 10.5' x 3.7' object is definitely worth a look in its own right.

Despite these attractions, there's a veritable plethora of other galaxies surrounding NGC 7331. Even though they rest just arcseconds away, none of these are bona fide, gravitationally bound satellite galaxies.

Curiously, NGC 7320, the largest member of Stephan's Quintet, lies the same distance from Earth as 7331, which suggests they may have been gravitationally associated in the distant past.

Moving from the north, four other galaxies surround NGC 7331: NGC 7336 (magnitude 15.8), NGC 7335 (13.3), NGC 7340 (13.7), and NGC 7337 (14.4). All lie on the eastern side of NGC 7331. Incidentally, of the nine galaxies originally catalogued as being next to NGC 7331, four turned out to be double stars mistaken for galaxies. A fifth was apparently a star close to the galaxy.

Just as with observing the Helix, select a still, dark, dry night before attempting the companions of NGC 7331. — *R. S.*

---

behind. Use binoculars to scan just northwest of 2nd-magnitude Enif, the winged horse's nose, to find M15. This bright globular cluster is one of the finest in the heavens.

To the south and southeast of Pegasus swim Pisces the Fish, chased along by huge Cetus the Whale to the south.

North of Pisces is Andromeda the Chained Maiden with a misty patch of light that reveals itself as a great galaxy some 2.2 million light years away. In between the fish and the maiden lie tiny Triangulum the Triangle and Aries the Ram.

Just as we get comfortable with fall, up come the winter stars in the form of Auriga the Charioteer, Orion the Hunter, Taurus the Bull, and Perseus the Hero and rescuer of Andromeda.

The tiny, dipper-like Pleiades star cluster, also called M45, follows Perseus over the northeastern horizon after 8 p.m. local time to a position well above the eastern horizon by midnight.

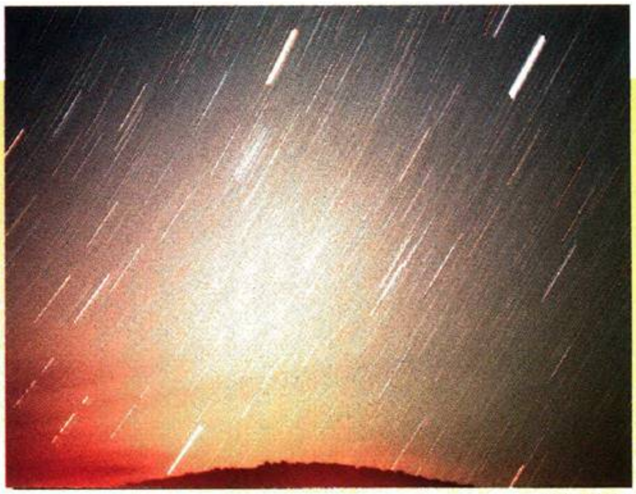
Once the luminaries of winter shine down from positions of prominence during the post-midnight hours, start looking low in the east for Leo the Lion and its accompaniment of planetary interlopers.

A wonderful pair of conjunctions take place in Leo this month. On the morning of October 4, **Venus** lies a Moon's width (0.5°) south of Regulus. There is a five-magnitude difference, or a factor of 100 times in brightness, between Venus and Regulus on this morning.

During the rest of October Venus moves away from Regulus, rising later each morning as it moves toward morning twilight.

A waning crescent Moon glides past **Mars**, Regulus and Venus on October 7, 8,

October's Ethereal Zodiacal Light



John Shibley

October mornings offer a good opportunity to view an example of "natural" light pollution: the zodiacal light. Look about two hours before sunrise along the horizon just a bit north of due east.

The light will look like a huge amorphous wedge extending from the horizon about 60° along the ecliptic. As the accompanying photo shows, the zodiacal light is only about half again as wide as it is tall.

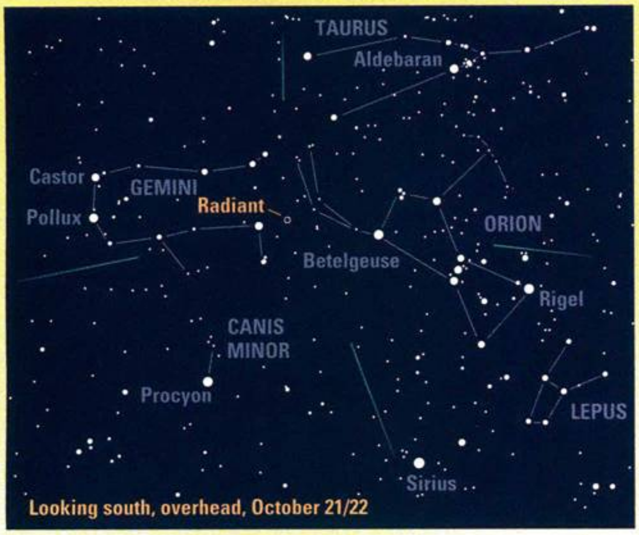
The instrument of choice for viewing the zodiacal light is your own two eyes. As with any low-light phenomenon, observe far away from the city, on dry, still mornings. Note any cities and towns that lie to the east of your observing site, so as to avoid mistaking manmade glow for zodiacal light.

What causes this huge wedge-shaped glow? Our first clue comes from it appearing near the horizon just before sunrise.

The next clue is that the ecliptic, the apparent path of the Sun and planets across the sky, bisects the glow. There's a lot of dust in the plane of the ecliptic, much of it deposited by spent comets. So the zodiacal light is sunlight being scattered and reflected by grains of dust along the ecliptic.

Fall is the best season to look for the zodiacal light in the morning from mid-northern latitudes because the ecliptic lies at a steep angle to the eastern horizon before sunrise. The light is also visible after sunset during the spring months, when the ecliptic rides steeply above the western horizon. — *R. S.*

Year of the Orionids



Looking south, overhead, October 21/22

Wallace Baldwin

The Moon spends October seemingly running over, by, or through something. Fortunately, it doesn't run into our view of the Orionid meteor shower.

The Orionids peak on the 21st, and usually provide 20 meteors per hour. The shower is active two days either side of the peak, so begin observing right after the Moon sets.

The Orionids are caused by dust particles released from the nucleus of Halley's Comet. The dust Halley's shed during its many passages through he inner solar system has spread into a gigantic particle fan.

Even though Halley's orbital inclination of 18° makes it impossible for the comet to hit Earth, its entourage of dust does intersect Earth's orbit.

Actually, the fan is made up of several separate streams of dust. We only know about two of these streams, the ones that cause the Eta Aquarid Shower in spring and the Orionids in the fall.

Because we're intersecting the orbits of these meteoroids as they approach perihelion, the closest point in their own orbits around the Sun, the Orionids are generally fast. Look for them to stream from the constellation of Orion, the shower's namesake. — *R. S.*

and 9, respectively, adding still more beauty to the dawn gathering.

As Venus falls away from Regulus, Mars moves in to take its place. Moving from adjacent Cancer, the Red Planet rests a little over 1° north of Regulus on the morning of October 29.

This conjunction presents a fine opportunity for a color photographic series showing Mars passing Regulus. Both are the same brightness, magnitude 1.4, but appear quite different. White Regulus contrasts wonderfully with the red/orange color of Mars. Brilliant Venus outshines them all at magnitude –4.0.

As if struggling not to be upstaged by its brighter siblings, **Mercury** comes up with its best morning apparition for 1996 early this month. The fleeting visitor stands 18° west of the Sun on October 3, shining at magnitude –0.5.

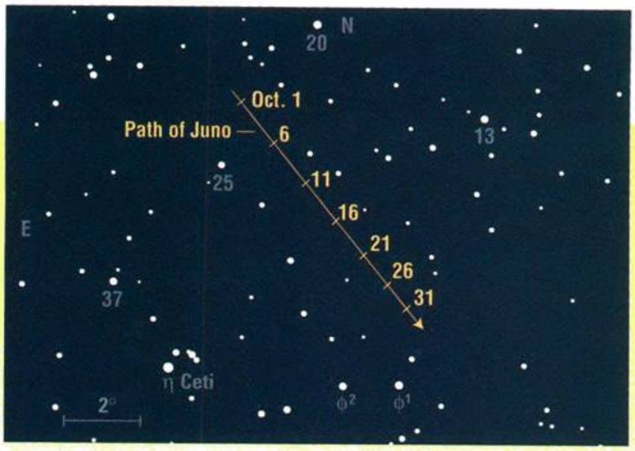
Mercury, however, won't be at its brightest until well after greatest elongation. On October 11, use binoculars to spot the innermost planet as a –0.9-magnitude star just 2.4° south-southeast of a very old crescent Moon that's one day before new.

The razor-thin Moon of October 11 has an appointment to keep with the Sun in just over 24 hours. On the morning of October 12, observers in northern Maine, northeastern Canada, Greenland, Iceland, Europe, and Africa will see it cross the northern corner of our Sun during a partial solar eclipse.

A total solar eclipse only happens when the new Moon crosses one of two nodes in its orbit that form a line with the Sun and Earth. On October 12 the Moon crosses its node *21 hours too early to yield a total eclipse.*

On top of that, the

Juno the Night Away



As if to celebrate the 39th anniversary of the launching of Sputnik, asteroid 3 Juno reaches opposition on the night of October 4. The 230-km diameter planetoid was the third asteroid discovered when it was found on September 2, 1804. This distinction belies the fact that Juno is 13th in size among the other asteroids.

Since Juno is relatively bright at magnitude 7.5, you can easily follow along in binoculars as it winds through the stars of Cetus the Whale. Look for it a bit north and west of Theta (θ) and Eta (η) Ceti.

Owners of CCD-imagers might undertake a project by measuring the asteroid's brightness at 30-minute intervals. Look for any variation to deduce a rotation rate. (Published values list a "day" of 7.2 hours.)

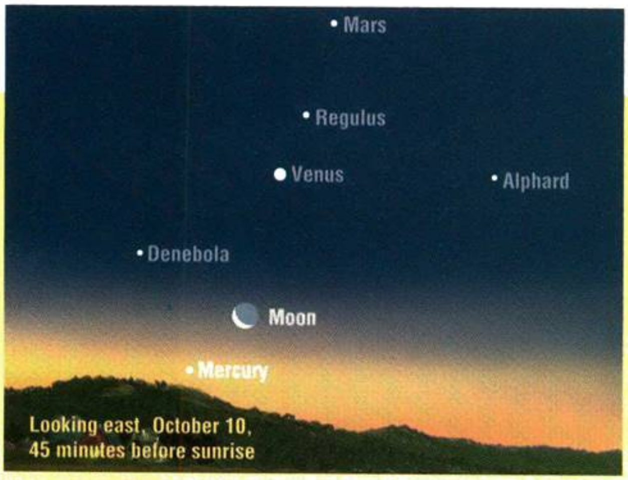
Remove any instrument error by measuring Juno's brightness relative to a nearby reference star of similar brightness.

Also, image Juno through three color filters to verify that Juno is a decidedly red object.

Believe it or not, its very red color might show up visually through a 16-inch or larger telescope.

Send any observations you make to ASTRONOMY magazine's Reader Reports column. — *R. S.*

Morning's Arrow to the Sun



Looking east, October 10, 45 minutes before sunrise

Those of us who get up an hour before sunrise on the morning of October 10 will be rewarded with an exquisite sight. Mercury, the Moon, Venus, the star Regulus, and Mars arrange themselves like a cosmic arrow that points to where the Sun is below the horizon.

Besides the obvious beauty, this conjunction allows you to compare and contrast several celestial objects.

First compare the phases of Mercury, Venus, and the 28-day-old Moon. Their phases are so different because Mercury is actually on the other side of the Sun from us than our Moon, so we see a waxing-gibbous phase.

The same holds true for Mars and Venus as well. But because the Red Planet is a superior planet (one that orbits outside of Earth's orbit), it can't show nearly as much phase as the closer-in inferior planets, being restricted to an occasional gibbous phase through a telescope.

If phases aren't your thing, try doing some rough visual spectroscopy. Because the clouds of Venus uniformly reflect the Sun's light, use the planet as a "white light" standard for comparison to other planets and stars.

Note how different mineralogical compositions make Mercury look yellowish, the Moon appear gray-green, and Mars seem reddish.

Stars hotter than our Sun, like 22,000 °C Regulus, look decidedly blue. The star's color will look even more pronounced when Venus passes very close to Regulus on October 3 and 4. — *R. S.*

Moon also reaches apogee, its farthest distance from Earth, six days earlier, which places it even farther from the Earth. This causes the Moon's dark, umbral shadow to fall short of Earth by about 1 1/2 Earth diameters.

For observers in St. John's, Newfoundland, partiality reaches a maximum of 16% at 10:03 a.m. local time, with the Sun about 27° high in the southeast.

Across the Atlantic Ocean in London, England, the eclipse begins at 1:59 p.m. and reaches a maximum of 61% coverage at 3:19 p.m.

Vacationers taking an early winter vacation in the Canary Islands, not to mention working astronomers on La Palma, will experience a 14% partial eclipse at mid-afternoon. By the time our Moon's shadow reaches Moscow and Cairo the Sun will be setting.

It is worth repeating here that you should never look directly at the Sun without protection at any time. During eclipses more attention is given to the Sun, and hence there is an increased risk of eye damage. The safest solar observing method is to project the Sun's image onto a white card using binoculars or a small telescope.

After rendezvousing with Sol, our Moon waxes into mid-October night skies, but not enough so as to bother observers hunting for Orionid meteors during the early hours of October 21. This shower is debris from Comet Halley.

Some of this year's meteors were undoubtedly released from Halley's last passage through the inner solar system in 1986. Up to 20 swift meteors flash from Orion's shoulder each hour, often leaving glowing trails of ionized gas that linger for several seconds.

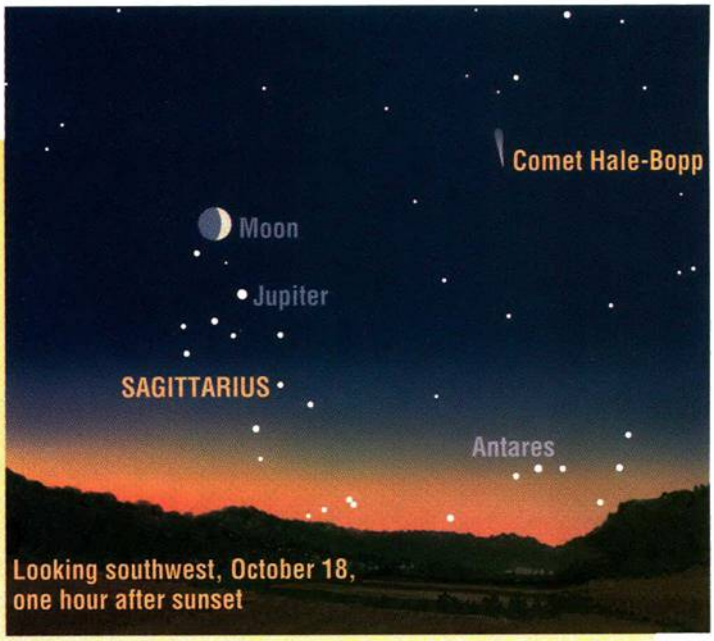
Eventually the night sky, meteors and all, surrenders to the overwhelming light of a full Moon on October 26. October's full Moon is also called the Hunter's Moon, a silent reminder to get provisions in order for the long, cold winter ahead.

October's Moon also reminds us to turn our clocks back early the next morning on October 27, when daylight saving time ends and 2 a.m. suddenly becomes 1 a.m.

Use the extra hour for a moonlight walk around your block in the crisp, autumn air. ☐

Martin Ratcliffe directs the Henry Buhl, Jr. Planetarium in Pittsburgh, Pennsylvania. Rick Shaffer is an engineer and writer living in Arizona.

Luna Salutes Jupiter and Hale-Bopp



Looking southwest, October 18, one hour after sunset

Old, reliable Luna offers itself up as a guidepost to a couple of outstanding celestial targets this month. On October 18, the six-day-old Moon lies 6 ½° above and to the left of Jupiter.

This line-up lets you inspect Jupiter and its Galilean moons, and then shift over to our Moon, which is roughly the size of Jupiter's companions.

Note that through a telescope, Jupiter's angular size is no bigger than the Moon's biggest crater. That's a trick of Jupiter's great distance (790,000,000 km) compared to the Moon's (370,000 km). Only the planet's great diameter of 142,800 km allows it to appear so bright and big through a telescope.

Shift your gaze about 27° above and to the right of the Moon to find our second target of the evening.

Binoculars should reveal a still-brightening comet Hale-Bopp in Ophiuchus shining at around 5th magnitude.

Hale-Bopp's brightness speaks of a large, active nucleus, one that's much larger than the nucleus of Comet Hyakutake. Despite its 449,000,000-km distance from us, the comet should be showing a tail by now. For more comet-viewing information see "See the Great Evening Comet" on page 81. — *R. S.*

The Moon in a Bull's Eye

Despite the fact that Taurus really doesn't resemble a bull in most people's minds, the title for this box is just too good to pass up.

The bright red star Aldebaran is, of course, the Bull's eye, and the large open cluster known as the Hyades makes up his face. (I'll leave the rest of the Bull to your imagination.)

On the night of October 28 our Moon drifts into this whole arrangement while the Bull rises in the east soon after sunset. By 1:30 a.m. EST, the Moon passes just north and west of Aldebaran.

Hardy observers in the frozen north of Alaska, northwestern Canada, as well as Scandinavia and the British Isles will see the Moon occult Aldebaran.

If you're an aspiring astronomer, use this event to roughly determine the Moon's orbital period.

Photograph it several times against the bright stars of the Hyades, and then, using a star atlas, determine how far the Moon moves between exposures. From this, compute how many days it takes to make one revolution around Earth. — *R. S.*

Galileo's Ganymede Surprise

Humanity's closest look yet at the solar system's biggest moon turned many a working theory about Ganymede on its head.

by John Shibley

Planetary science can be a nerve-racking way to make a living. Practitioners make confident predictions based upon conventional wisdom, knowing full well that new data will likely turn even the most fundamental of assumptions upside down.

Galileo's brush with Ganymede on June 27 did nothing to buck this tendency. In Ganymede's case, conventional wisdom, derived from two Voyager flybys more than 17 years ago, was turned on edge thanks to a closer view provided by Galileo's instruments.

Never What It Seems

Based upon Voyager pictures, Galileo project scientists targeted two different and distinct areas of Ganymede for close examination during June's flyby: Uruk Sulcus, a light-colored, younger terrain, and Galileo Regio, a darker, apparently older expanse to the north.

Conventional wisdom said Uruk would probably harbor evidence for water volcanism, with a landscape covered by frozen water belched up from beneath Ganymede's crust. Galileo Regio, on the other hand, would be wall-to-wall craters, an expanse relatively unchanged since the pummeling it took during the first third of our solar system's lifetime.

Planners selected a sequence of four pictures for each region, each image covering an area roughly the size of Rhode Island. Scientists hoped their Voyager constructs would stand up to the Galileo magnifying glass.

So much for conventional wisdom.

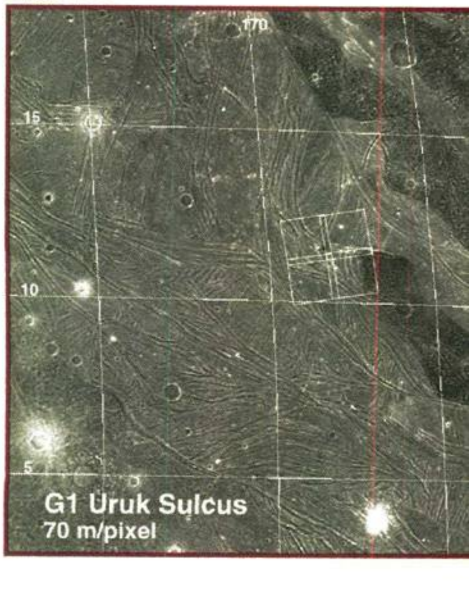
It turns out Uruk is crisscrossed by relatively younger parallel grooves that cut across a preexisting, heavily-grooved terrain. Such widespread features mark contact points where tectonic zones moved away from one another as Ganymede's icy surface cooled and expanded. The grooves show that tectonics, not so much volcanism, carried the day when it came to defining Ganymede.

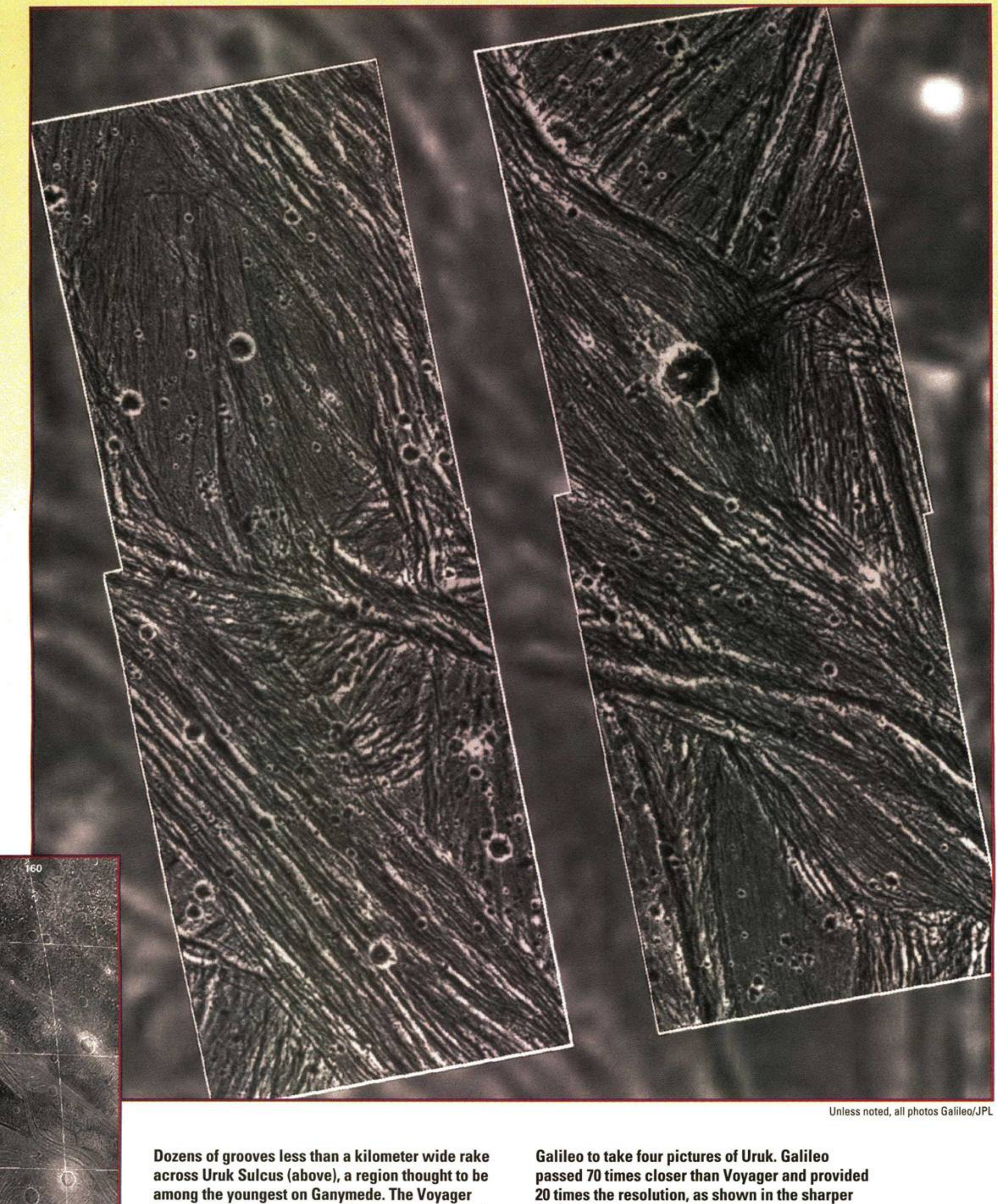
"Tectonics, rather than water volcanism, played a major role in shaping the lighter areas," project scientist Torrence Johnson confessed during a July news conference that presented the pictures. "Faulting, not flooding, destroyed many of the older craters."

Even ungrooved Galileo Regio pointed to some of the same tectonic processes that shaped Uruk. A close look revealed crater walls cleaved by narrow fractures. "At some time in its history, all of Ganymede was affected by tectonic forces, more so than we ever thought from the Voyager data," Johnson admitted.

And as if to confound the pros even more, it's the much older Galileo Regio that may harbor telltale traces of volcanic activity in its alternating patchwork of light-

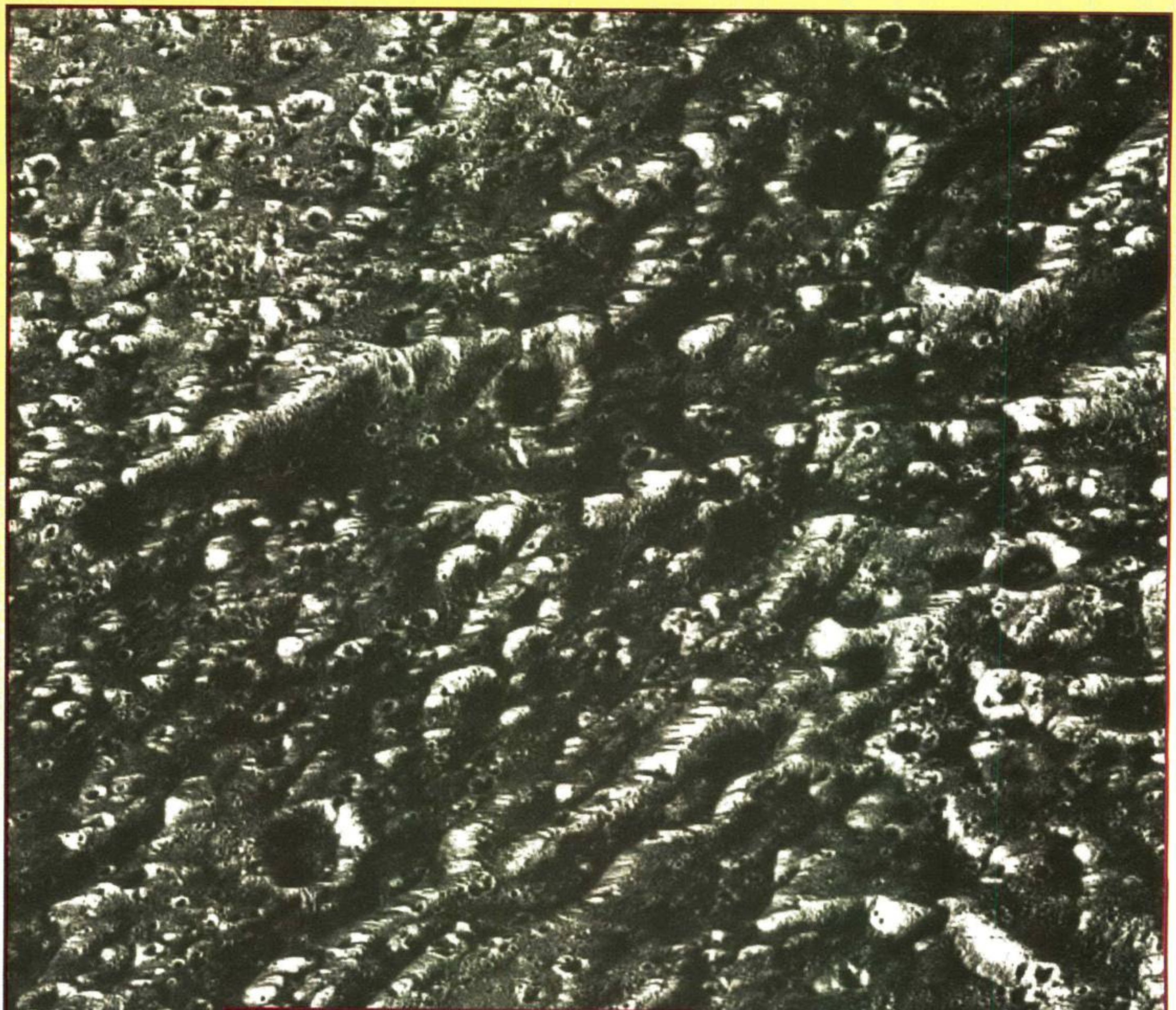
Voyager 2/JPL

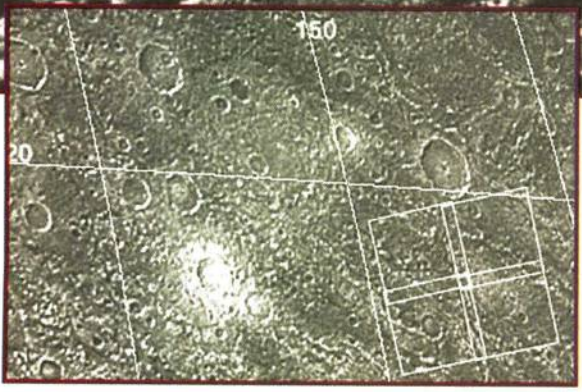




Unless noted, all photos Galileo/JPL

Dozens of grooves less than a kilometer wide rake across Uruk Sulcus (above), a region thought to be among the youngest on Ganymede. The Voyager image at left shows where scientists programmed Galileo to take four pictures of Uruk. Galileo passed 70 times closer than Voyager and provided 20 times the resolution, as shown in the sharper frames above.

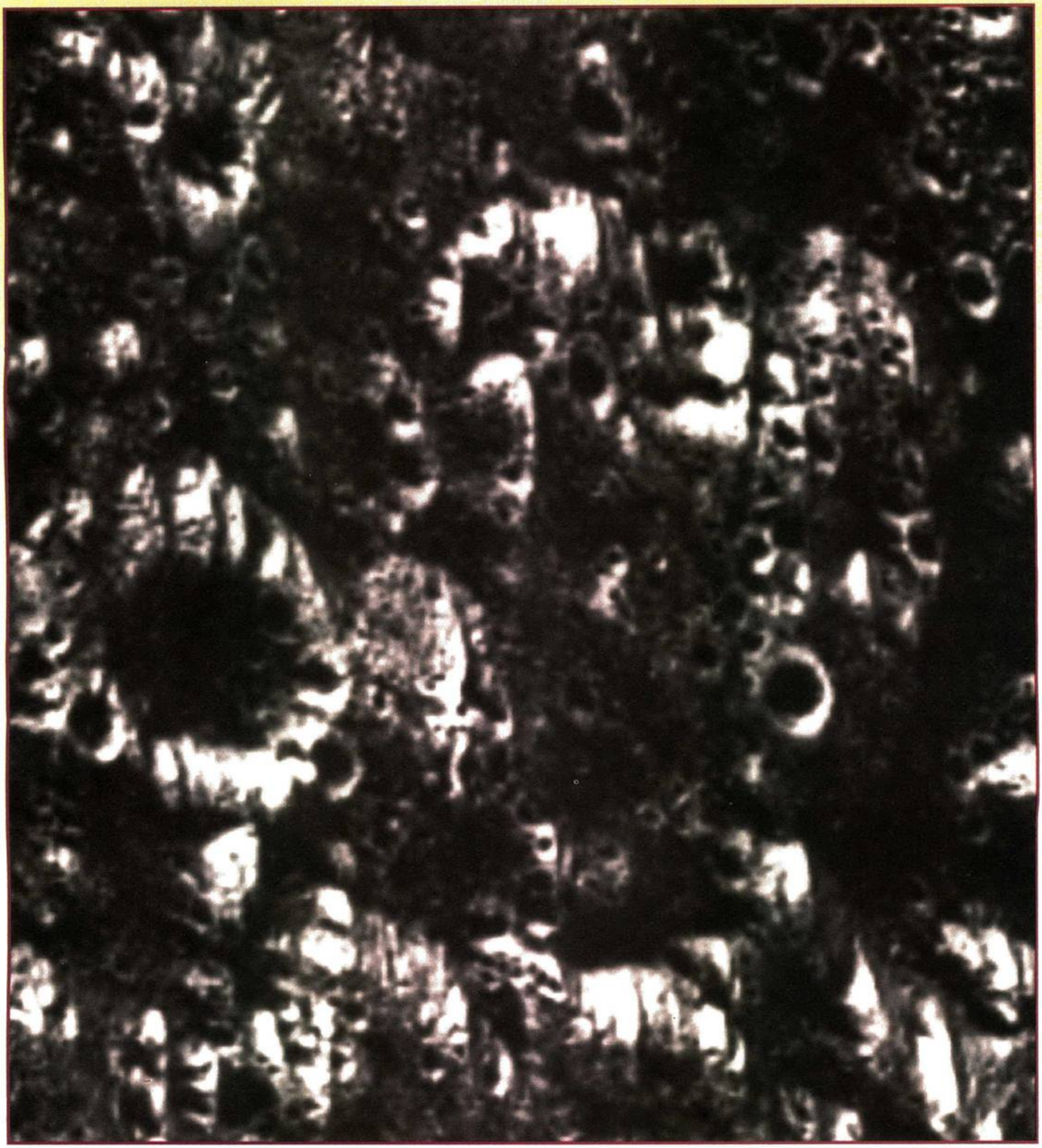




Voyager 2/JPL

North of grooved Uruk lies Galileo Regio, a darker, somewhat older part of Ganymede. Project scientists planned four close-up photos of this region as well (left, Voyager image). In one pictured above, we see bright hummocks surrounded by darker soil. The dark material could be the result of exposure to eons of solar radiation, or perhaps a dusting from meteorite debris. Meandering through this view are large fault-like features that deform an otherwise uniformly-cratered surface. Some of the same processes that shaped younger Uruk to the south influenced Galileo Regio as well. Such widespread faulting came as a surprise to Galileo project scientists.

Another Galileo Regio close-up (below) betrays still more subtleties. The large, white-outlined crater to the left, three inches from the picture's bottom, is cleaved by parallel fractures, further evidence of fracturing caused by movements within the very crust of Ganymede itself. Some of the dark features might betray the presence of long-dormant volcanic vents that violently spewed water upon the moon's surface billions of years ago. Further study, and three more flybys of Ganymede by the Galileo spacecraft, might shed more insights on this issue.



shaded hillocks and darker soils. Galileo investigators had originally hoped to find such signs in Uruk Sulcus to the south.

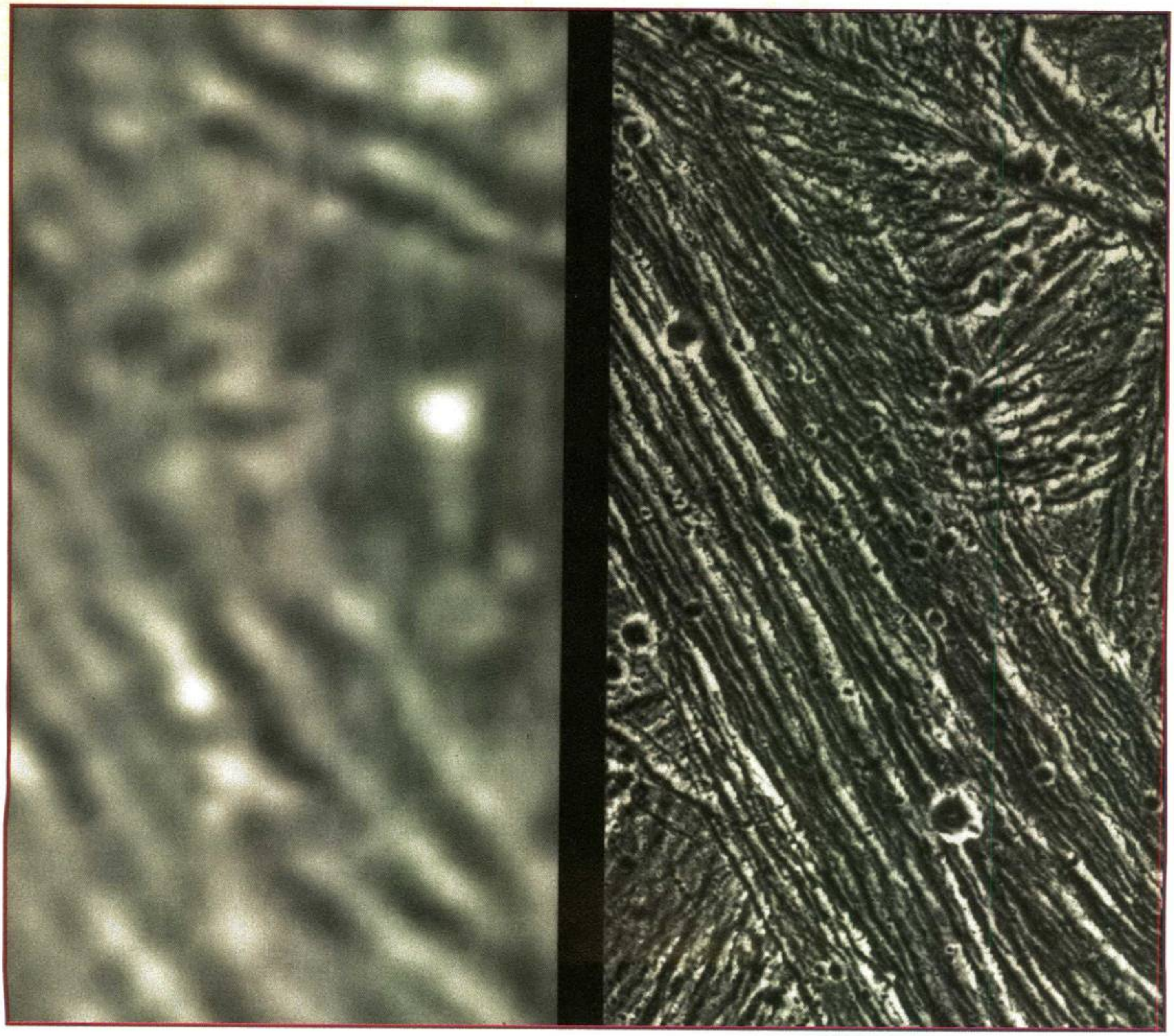
Brighter splotches interspersed among Galileo Regio's cratered landscape might mark the rims of ancient craters poking through an altered surface. Some of the darker streaks might be dark material deposited by meteorites or volcanic vents locked in the embrace of a sleep that's lasted for billions of years.

Not Dead Yet?

But all may not be as dormant as it seems.

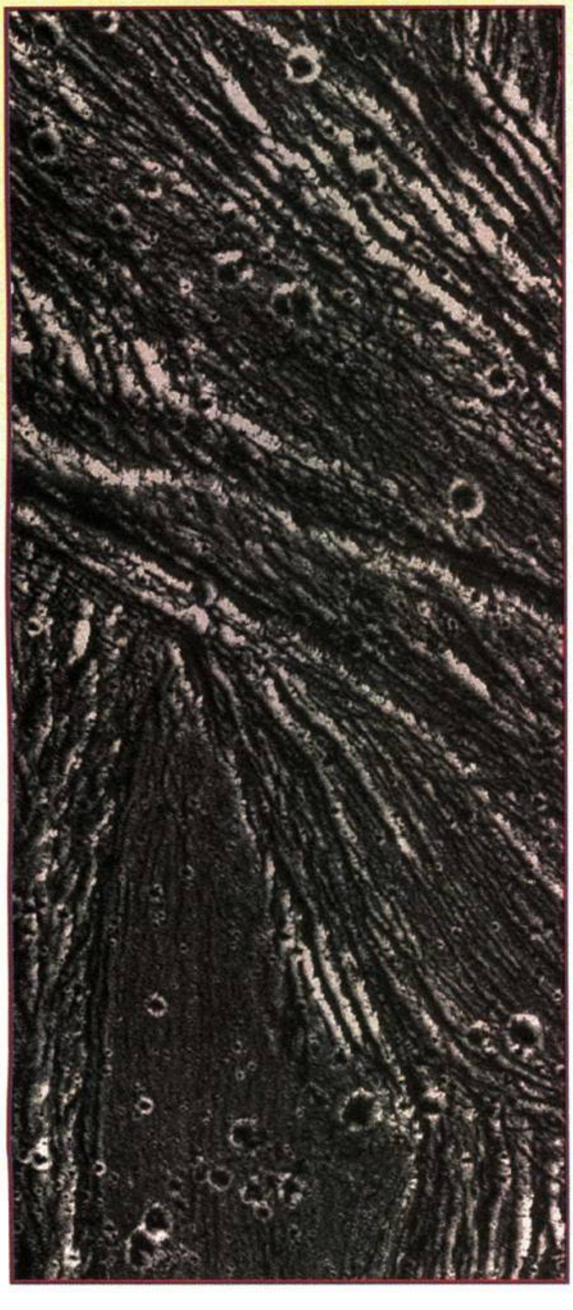
As Galileo closed in on Ganymede it detected the signature of high-energy radiation, evidence of a moon-wide magnetic field. Even the craft's magnetometer logged a fivefold jump in field strength that shifted in Ganymede's direction during the flyby. Such a field hints at a not-so-sleepy Galilean satellite with electrical currents coursing through a subsurface layer of salt water.

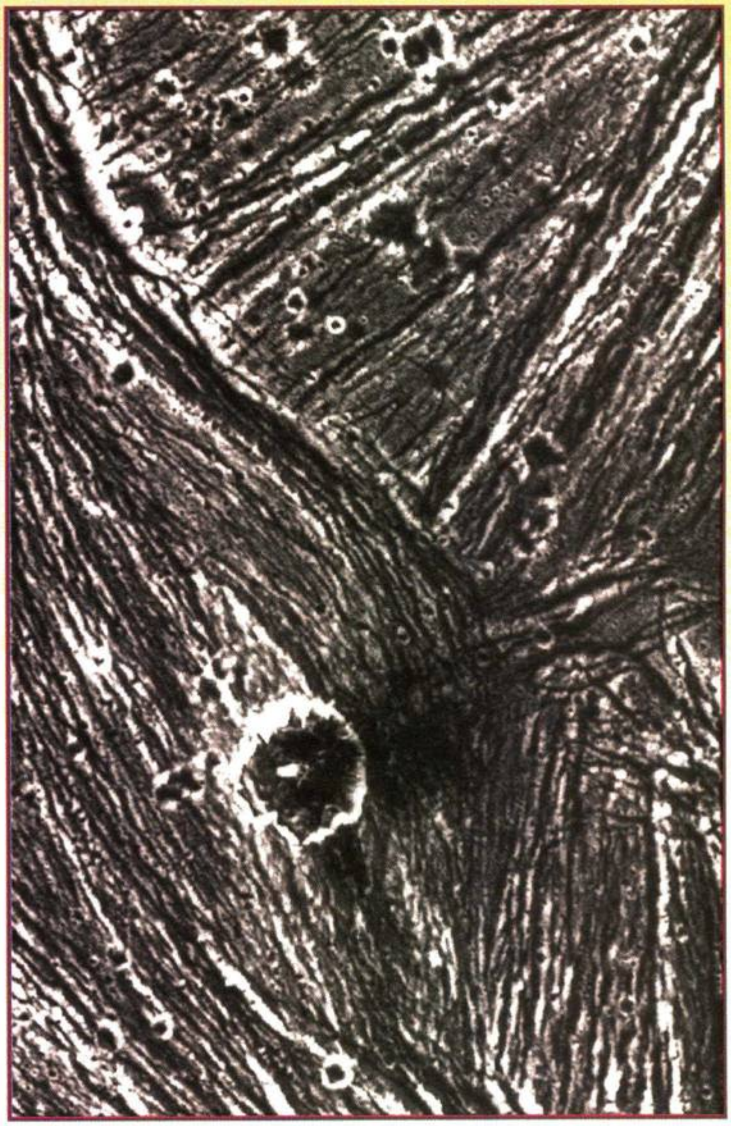
Scientists are presently analyzing how Galileo's motion was altered when it passed by Ganymede in hopes of deducing what layers really lie beneath the moon's enigmatic exterior. They can't rule out a molten-iron core, a factor largely responsible for the magnetic field in Io, another large Jovian moon that orbits



Here's what a better camera positioned a lot closer will do for you. Voyager 2's sharpest frame of Uruk Sulcus (left) revealed a blur of five distinct ridges. It shows detail down to 1.3 kilometers. Galileo's next-generation camera, coupled with the spacecraft's 7,448-km vantage point, splits what were five ridges into a network of 40 (right). Surface detail down to 74 meters can be glimpsed.

Sixty percent of Ganymede's surface is crisscrossed by these networks of grooves and ridges (below), formed when the moon's largely water-saturated surface cooled and expanded to form these features. The grooves are areas of extension (pulling apart) that arrange themselves into broader tracts of shear (horizontal sliding).





Another detail of Uruk (above) unveils a mixture of terrain. An older, pockmarked region lies to the upper right of this photo measuring 42 by 62 kilometers in size. The grooved portion to the left, with its relative lack of craters, is much younger. One recent impact crater overlies some grooves, its dark ejecta draped upon the surrounding topography. Scientists had thought Uruk would show evidence of water volcanism in the form of a smooth, white surface. No such definitive signs of volcanism were found.

closer to Jupiter (see "Getting to Know Jupiter & Company," August 1996 AstroNews).

Fortunately, investigators have three more Ganymede flyby opportunities through next May to gather data on the field, which is a thousandth the strength of Earth's. A September 6th flyby comes to within 255 kilometers, as compared to June's 835-kilometer distance.

Such a close pass should radically modify still more cherished assumptions put forth by a generation of scientists who were, at best, graduate students during the Voyager flybys. Come November 1997, two more Jovian worlds, Europa and Callisto, will come under Galileo's battery of instruments to take their shot at the intellectual equivalent of a carnival dunk tank.

What ideas within the planetary science community will sink or swim is anybody's guess. ☐

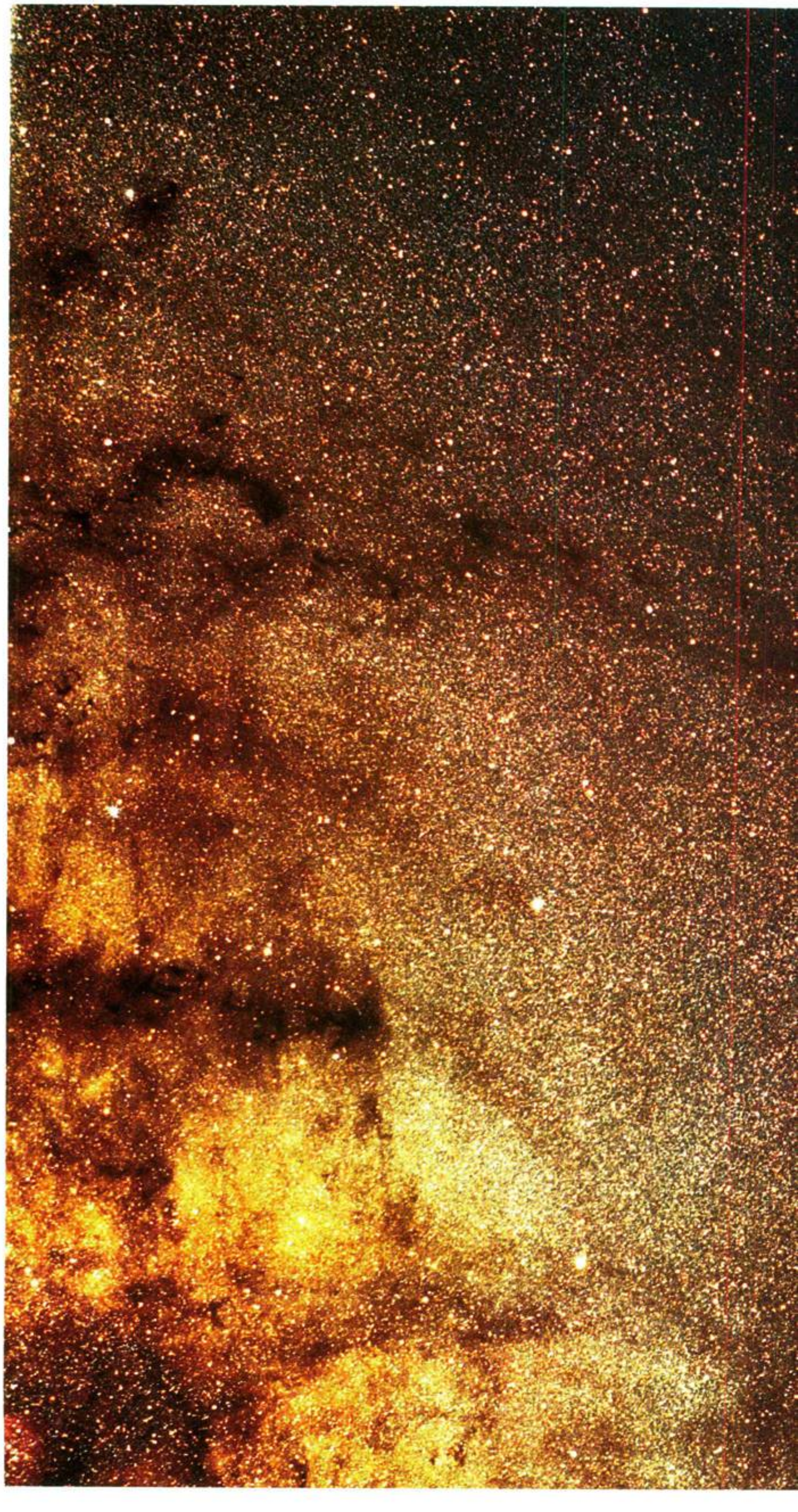
Kodak's Hot New

Get ready to have your whole view of color astrophotography changed. Right now.

by Tony Hallas

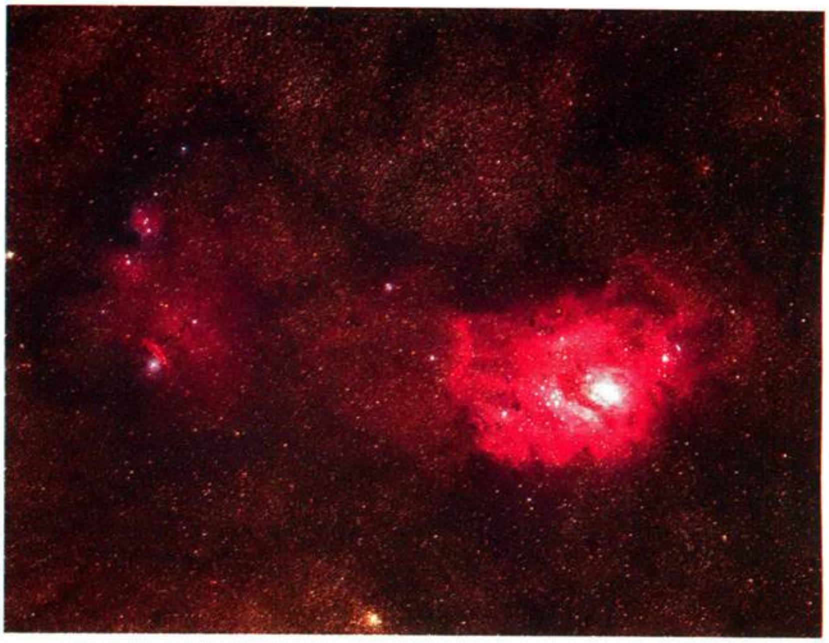
Gone are the days when Fuji Super HG 400 ruled the skies. Now there's a new boss in town. It's a high contrast color negative film that, due to its exceptional qualities for astro subjects, is poised to revolutionize sky photography. Four primary attributes make the film superior to any color film I've previously seen. When I developed and finished the images you see in this story and on the contents page of this issue, I was amazed. The story of the discovery of this film goes back to early in the year.

Tony and Daphne Hallas


Tony and Daphne Hallas

ABOVE: An extreme enlargement from a 35mm PPF frame demonstrates the film's ability to contain light in very small areas, yielding pinpoint stars, over very short exposures. This image of the globular cluster M5 in Serpens was made using hypered PPF, a 7-inch f/7 apo refractor, and a single 10-minute exposure. **RIGHT:** *The multicolored splendor* of the Rho Ophiuchi region, laced with dark lanes, comes alive in unexcelled detail in this exposure made with PPF film. It is a composite of two 20-minute exposures made with a 165mm lens at f/5.6 and hypersensitized 120 format film.

Astrophoto Film



Tony and Daphne Hallas

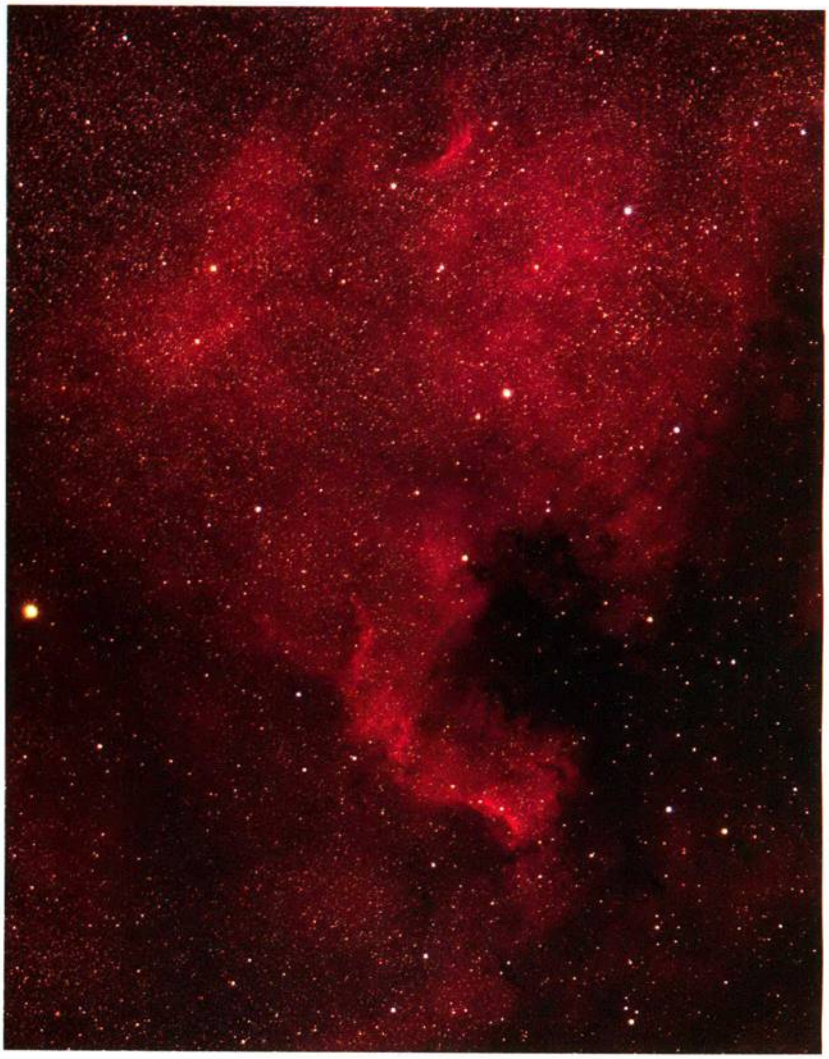
Pinpoint stars and high resolution details characterize PPF's performance on a rich area of nebulosity like the Lagoon region in Sagittarius. Tiny dust clouds in the Lagoon and in the complex of nebulosity at left (NGC 6559, IC 1274, IC 1275, and friends) testify to the film's amazing sharpness. Note the golden color of globular cluster NGC 6544 at bottom. This is a composite of two 30-minute exposures on hypered PPF taken with a 7-inch f/7 apo refractor.

News about a new superfilm first trickled through the amateur astronomy community at the Winter Star Party in the Florida Keys in February 1996. A group of European skyshooters turned us Americans onto what is called Kodak Pro Gold 400 across the big pond. I subsequently found no such film available in the United States.

Through my photo lab, I contacted a film specialist at Kodak who told me this color negative film is simply called Pro 400, or PPF, here in the States. At this time I also received a shipment of 20 rolls of Pro Gold 400 from the German astrophotographer Thomas Baader. The first test results knocked me over.

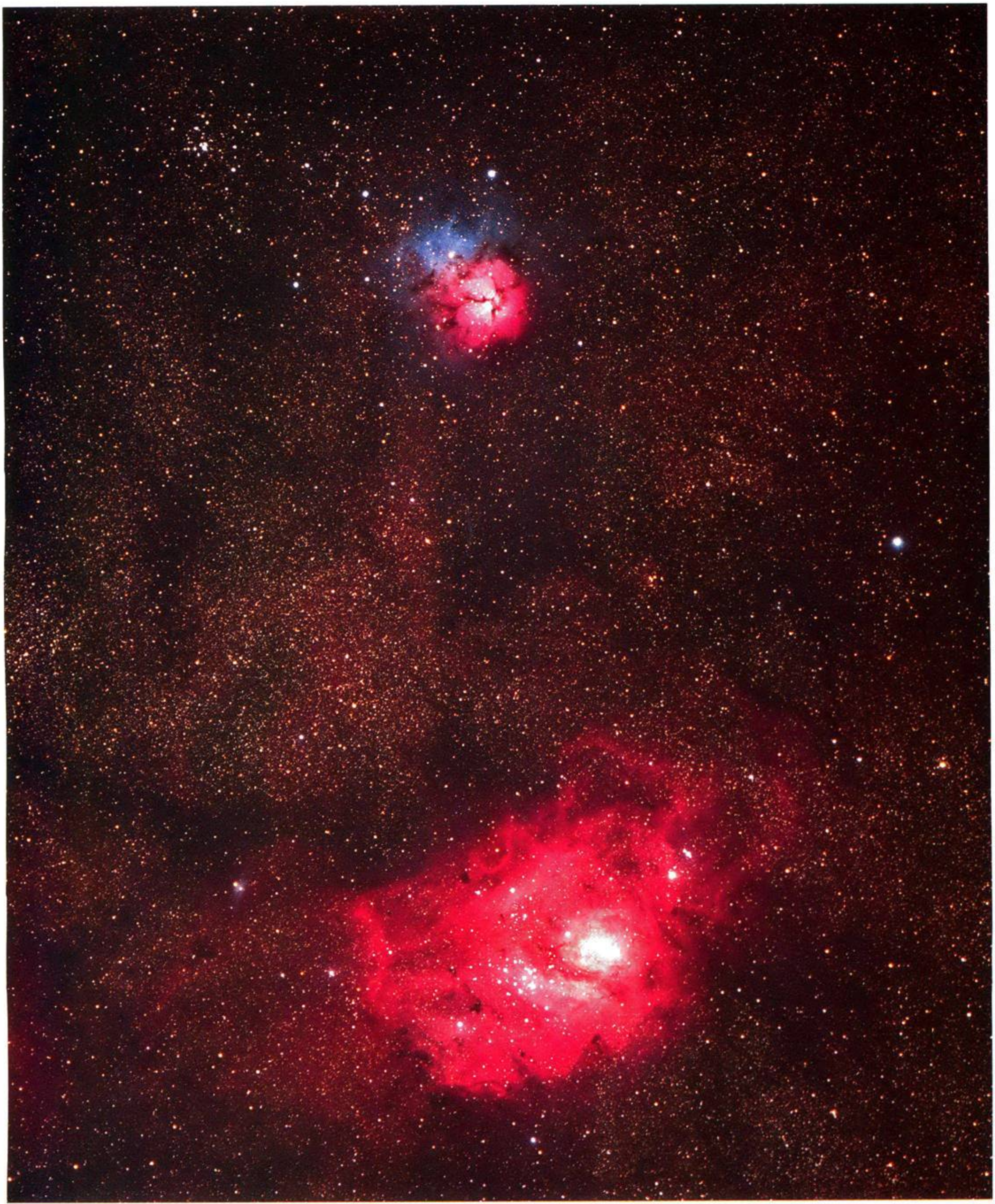
The four amazing attributes of this film are as follows. First, the film utilizes T-grain technology that yields very fine grain and high sharpness on a level previously captured only with black and white films. Second, the emulsion has what Kodak calls a solid particle filter dye. This prevents light from one of the color layers from scattering to the next, yielding very sharply defined stars and ultra high contrast. Third, improved electron trapping results in extremely low reciprocity failure — this means that the film works very efficiently, requiring only very short exposures. Fourth, the film has been formulated to produce bright colors even when it's underexposed or overexposed.

Using a calibrated test bench, I put a roll of this stuff to work. Right away, PPF showed great promise. I exposed the film without hypering it and got good results. Then I pushed the processing and found a slight improvement, but the film became too



Tony and Daphne Hallas

The North America Nebula comes alive in razor-sharp definition as shot on PPF. Star colors over the field reveal a striking range of blue-white to deep orange. Fine details stand out in the myriad of stars comprising the faint cluster NGC 6996 (upper right) and the much fainter cluster Collinder 428 (upper left). This is a composite of two 30-minute exposures on hypered PPF taken with a 7-inch f/7 apo refractor.



Tony and Daphne Hallas

The Lagoon and Trifid nebulae imaged together demonstrate the amazing range of color offered by PPF. Not only are the ruddy hues of the bright portions of the Lagoon present (bottom), but also the faint, crisp bluish hue of dust in the Trifid (top). This image is a composite of two 30-minute exposures on hypered PPF taken with a 7-inch f/7 apo refractor.

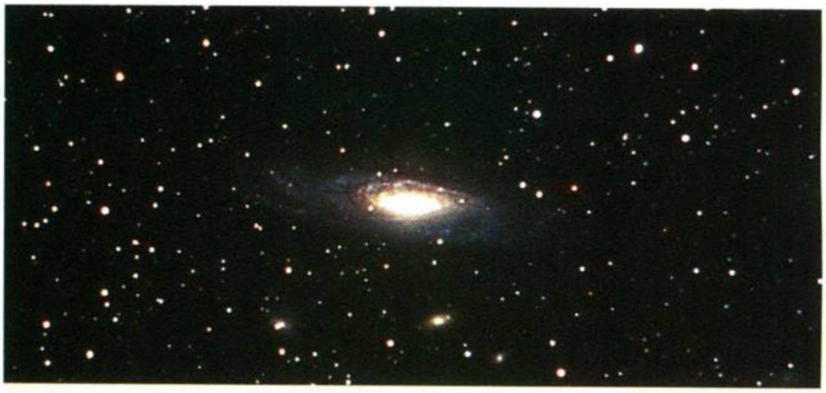
grainy and the film base produced a terrible stain. Finally, I hypersensitized the film and tested a roll. The blue response took off like a rocket ship while the red, yellow, and green response still looked good.

It became clear that, when hypered, PPF is a knockout film. The images in this article were made with a 7-inch f/7 apo refractor and an 11-inch SCT at f/10. The film performed like a champ in both situations. Not only is the color balance terrific, with such good blue response, but the film is super fast. The exposure times with the refractor were only 30 minutes — any longer and the negative fogged up! For those of you who hyper your own film, it became clear that PPF requires only ⅔ the hypering time required by Fuji Super HG 400. The film is available in both 35mm and 120 formats.

The images presented here are only initial results, first attempts. Indications are that the film used for these images was somewhat underhypered and that future results will be better still. In my many years of working with color, I've never seen a film like this. I've already dubbed PPF "perfect photographic film."

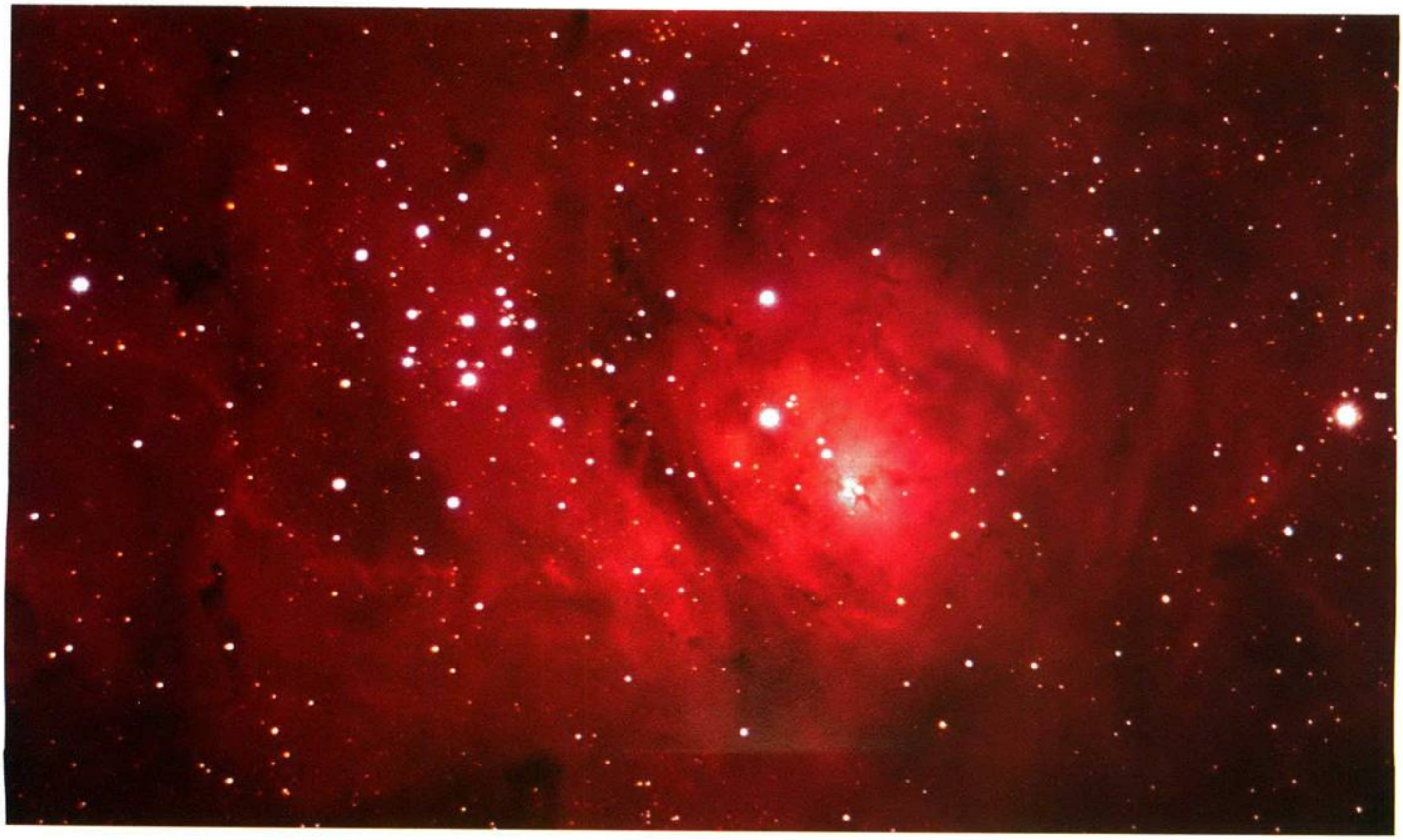
It clearly has the potential to redefine the way we think about conventional astrophotography. It's like starting from scratch. ☐

Tony Hallas is one of the world's leading photographers of deep-sky objects. Along with his wife Daphne, he routinely fires shutters from his perches on Mt. Pinos and Pine Mountain, California, and many of the results — galaxies, nebulae, and star clusters — have appeared in past issues.



Bob Fera

ABOVE: PPF film now makes possible detailed, color portraits of galaxies previously relegated to the world of black and white. The dust lanes in NGC 7331 in Pegasus wrap tightly about its brilliant hub. This is a composite of two 75-minute exposures on hypered PPF made with an 11-inch f/10 SCT. BELOW: No longer does color deep-sky astrophotography belong to the fast astrophoto system. This magnificently detailed closeup portrait of the Lagoon Nebula is a single 40-minute exposure on hypered PPF, made with an 11-inch SCT at the slow photographic "speed" of f/10. The razor-sharp detail of the Hourglass at center is astonishing!



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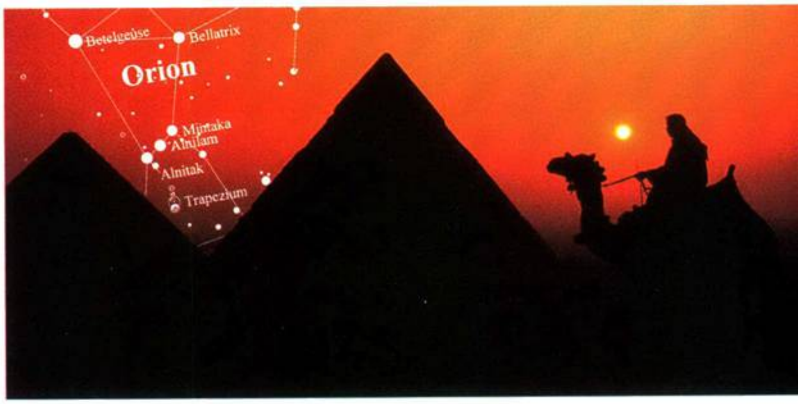

New theories have linked the positioning of Egypt's ancient pyramids with the celestial orientation of the three stars in Orion's belt. What discoveries await you in TheSky?

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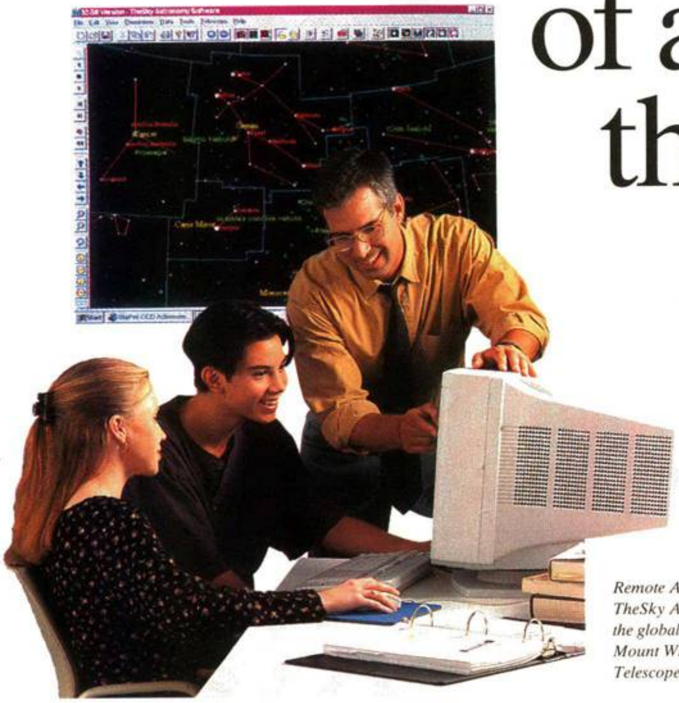

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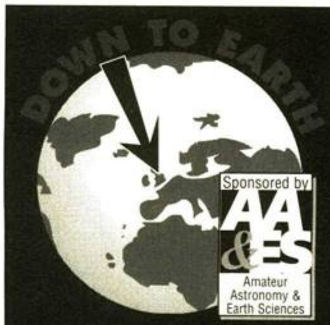

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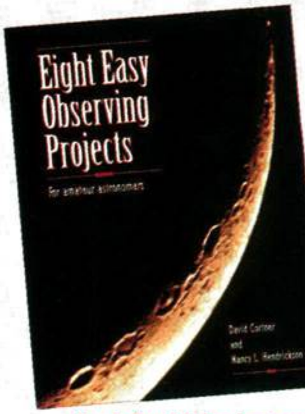
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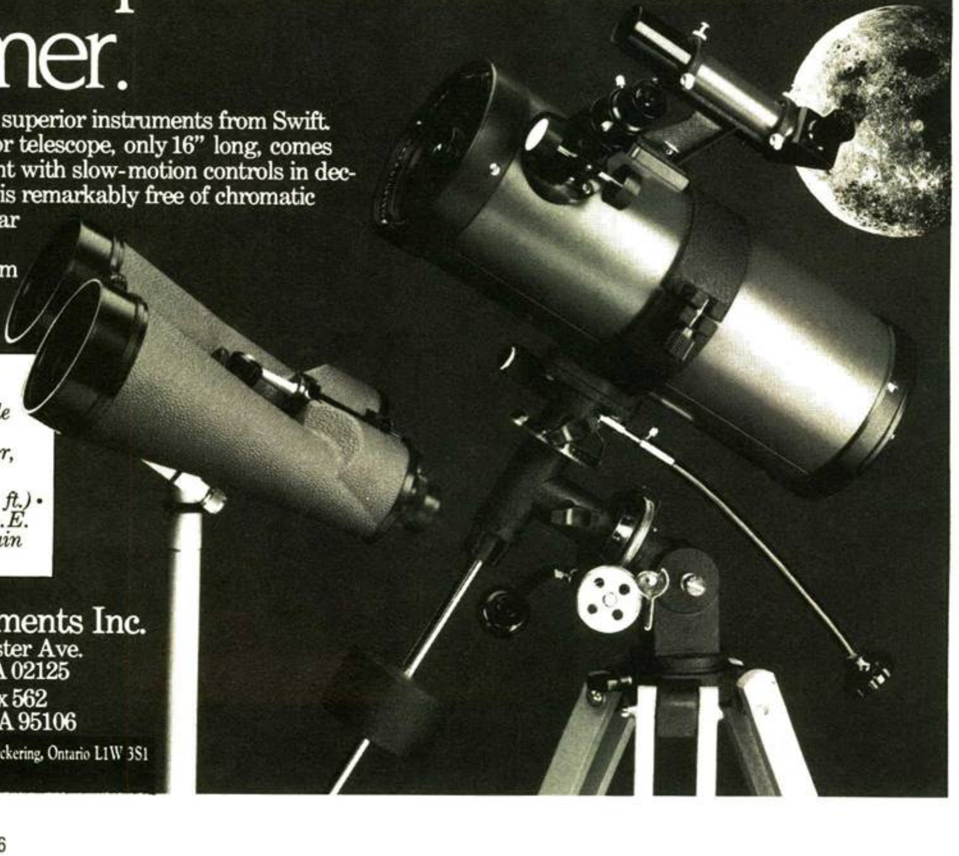
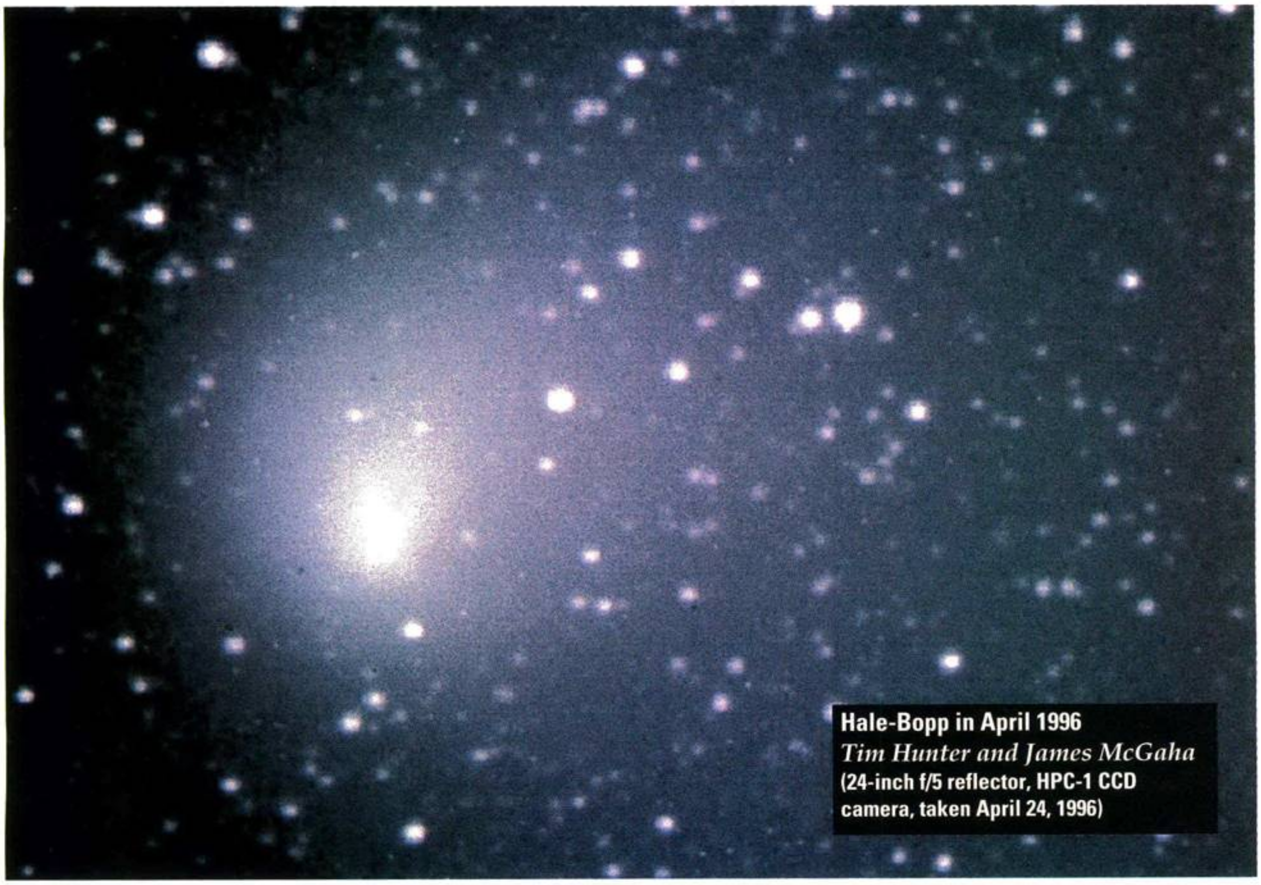


See the Great Evening Comet

Hale-Bopp rises to naked-eye prominence in the chilly evening skies of October and November.

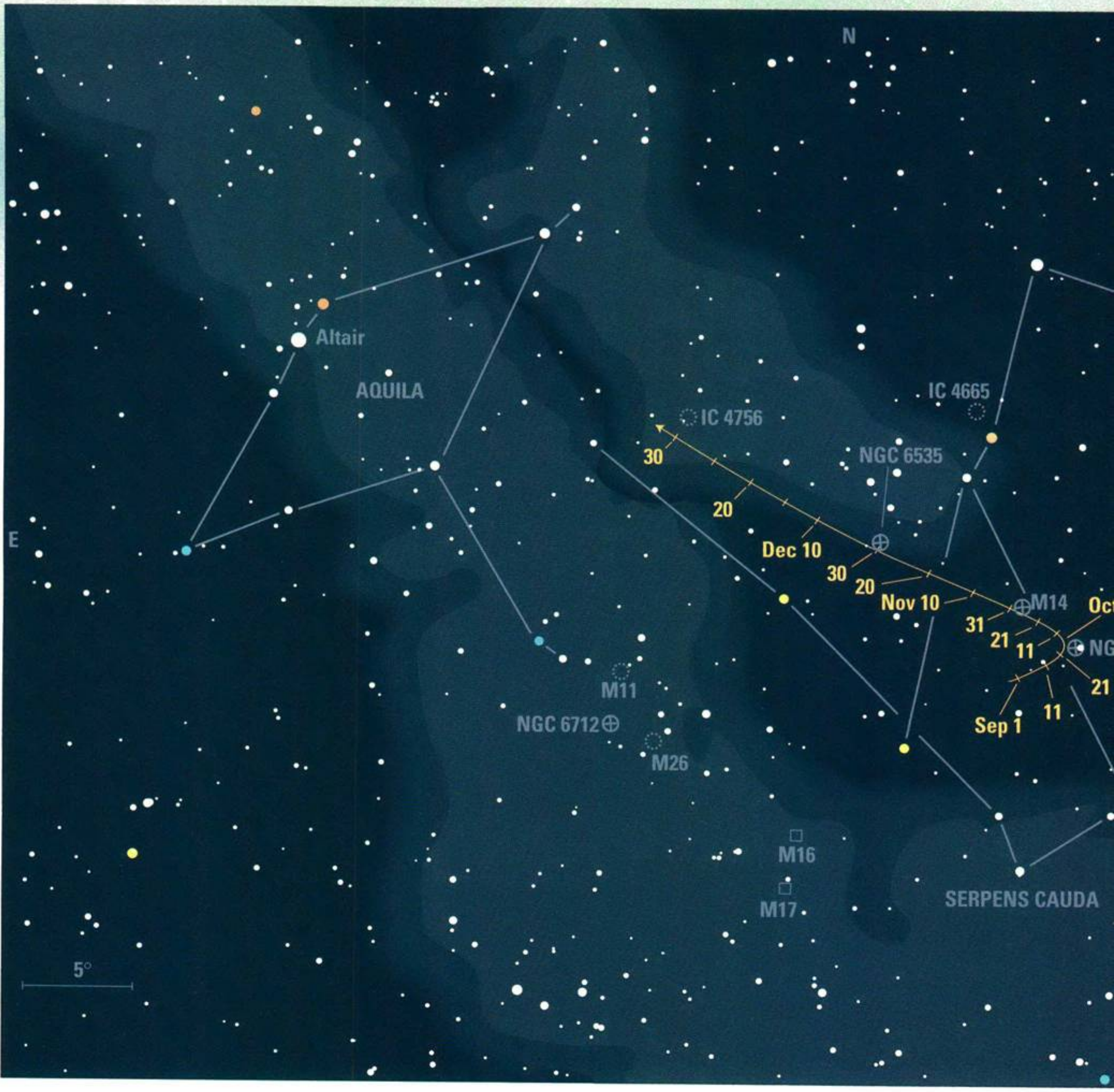
by David J. Eicher



Hale-Bopp in April 1996
Tim Hunter and James McGaha
(24-inch f/5 reflector, HPC-1 CCD camera, taken April 24, 1996)

Last year's apparition of the bright Comet Hyakutake (C/1996 B2) hit the astronomical community like a missile. The sight of a bright coma and lengthy tail induced a mass exodus into backyards the world over, where myriad observers admired the beautiful comet.

As it often does, however, lightning strikes twice this decade. A second bright comet, Hale-Bopp (C/1995 O1), will soon grace our evening skies. But this one stands to be brighter yet and will hang around for a much longer period. Hold on for the cometary event of the decade — possibly longer.



ASTRONOMY: Lee Vande Visse

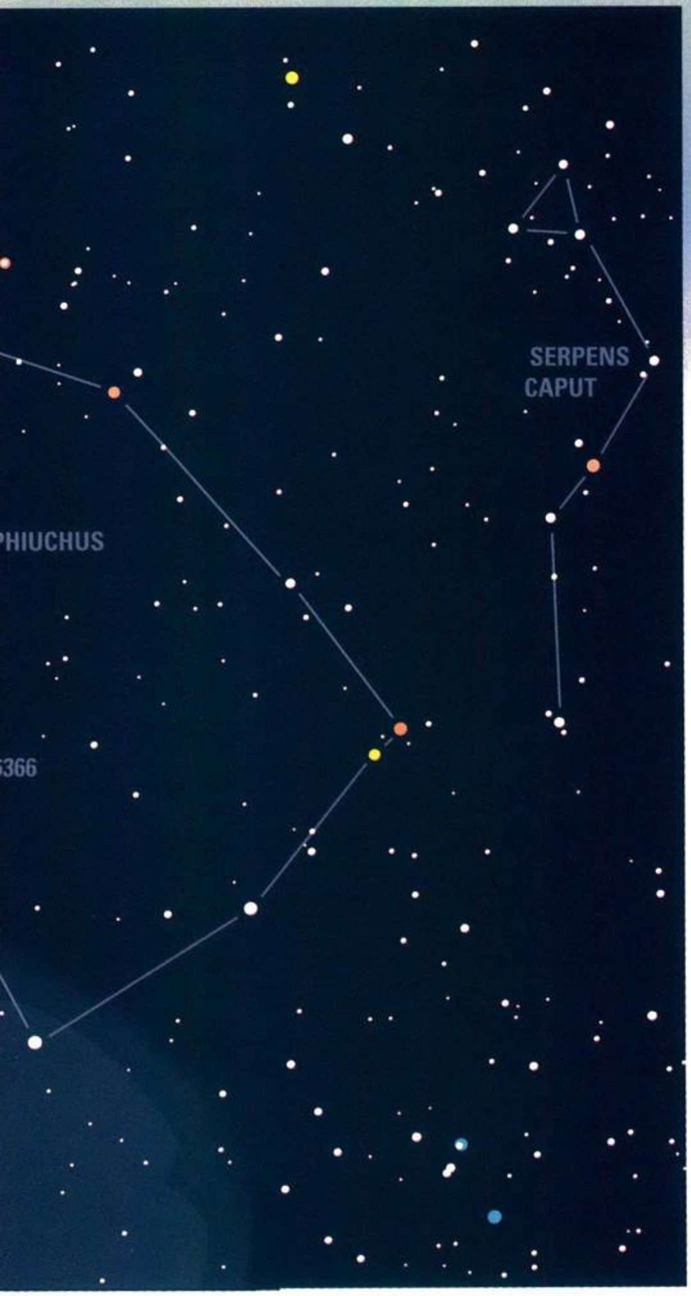
The big show from Hale-Bopp comes next spring. For the next couple of months we'll see the comet hang conveniently in the evening sky and ramp up in brightness from 5th to 3rd magnitude. It will thus go from a pretty object in binoculars that is faintly visible to the naked eye, to a pretty respectable sight to the eye alone.

The comet will move slowly northwest in Ophiuchus and then turn northeast as it climbs into Serpens Cauda. The comet's tail will undoubtedly grow during this period from a stub to a ghostly apparition several degrees long, although the behavior of comet tails can leave anyone guessing. The comet also passes relatively close to a succession of bright deep-sky objects, offering astrophotographers the chance to capture pretty, wide-field images on film or with CCDs. Capturing your own keepsakes will thus be easy.

September: A Great Binocular Comet

Hale-Bopp begins September as a 5th-magnitude object already in view as darkness falls, placed well up in the southwestern evening sky. Located between the bright stars Nu (ν) and 47 Ophiuchi, the comet slowly moves to the northwest as the month progresses. By month's end the comet reaches its westernmost point and turns northeastward, gaining declination and moving toward Serpens Cauda. On the last day of September Hale-Bopp's nucleus lies within the same low-power field as the 10th-magnitude globular cluster NGC 6366, itself some 30' east of 47 Oph.

The best times to view the comet come during the first half of September, as the Moon moves back into the evening sky by midmonth. Early in the month it is visible by about 8:30 p.m. local time and sets by about midnight; by midmonth darkness falls around 7:45



p.m. local time and the comet slips under the horizon about 10:50 p.m. Hale-Bopp's increase in brightness will be gradual; it opens September at magnitude 5.4 and rises to 5.0 by the end of the month. During this period the comet's distance from the Sun decreases from 484 million kilometers to 430 million km; its distance from Earth increases from 422 million km to 447 million km.

October: As Good as Halley's Comet

As October brings cooler temperatures to the Northern Hemisphere, Hale-Bopp brightens and presents itself for a reasonably long stretch each evening in the southwestern sky. The comet inches slowly northeastward through Ophiuchus and ends the month less than a degree east of the 8th-magnitude globular cluster M14 (NGC 6402). During this period the comet's

Where to Find Comet Hale-Bopp

Date	R.A.(2000)	Dec.	Mag.	Constellation
Sept. 1	17h38.9m	–6°32'	5.4	Ophiuchus
Sept. 15	17h31.9m	–5°46'	5.2	Ophiuchus
Oct. 1	17h29.6m	–4°59'	5.0	Ophiuchus
Oct. 15	17h32.0m	–4°17'	4.8	Ophiuchus
Nov. 1	17h39.8m	–3°18'	4.5	Ophiuchus
Nov. 15	17h49.5m	–2°14'	4.1	Ophiuchus
Dec. 1	18h04.1m	–0°35'	3.7	Serpens Cauda
Dec. 15	18h19.7m	1°24'	3.2	Ophiuchus
Jan. 1, 1997	18h42.5m	4°48'	2.6	Serpens Cauda

Along with the date, this table provides the comet's position in right ascension and declination (epoch 2000.0), equivalent to longitude and latitude on the sky. The magnitude is a measure of the comet's brightness: the faintest stars visible to the naked eye glow at about magnitude 6, the brightest at about magnitude –1.5. The brighter the comet gets, then, the smaller the number. The constellation column shows which bright star group the comet appears near.

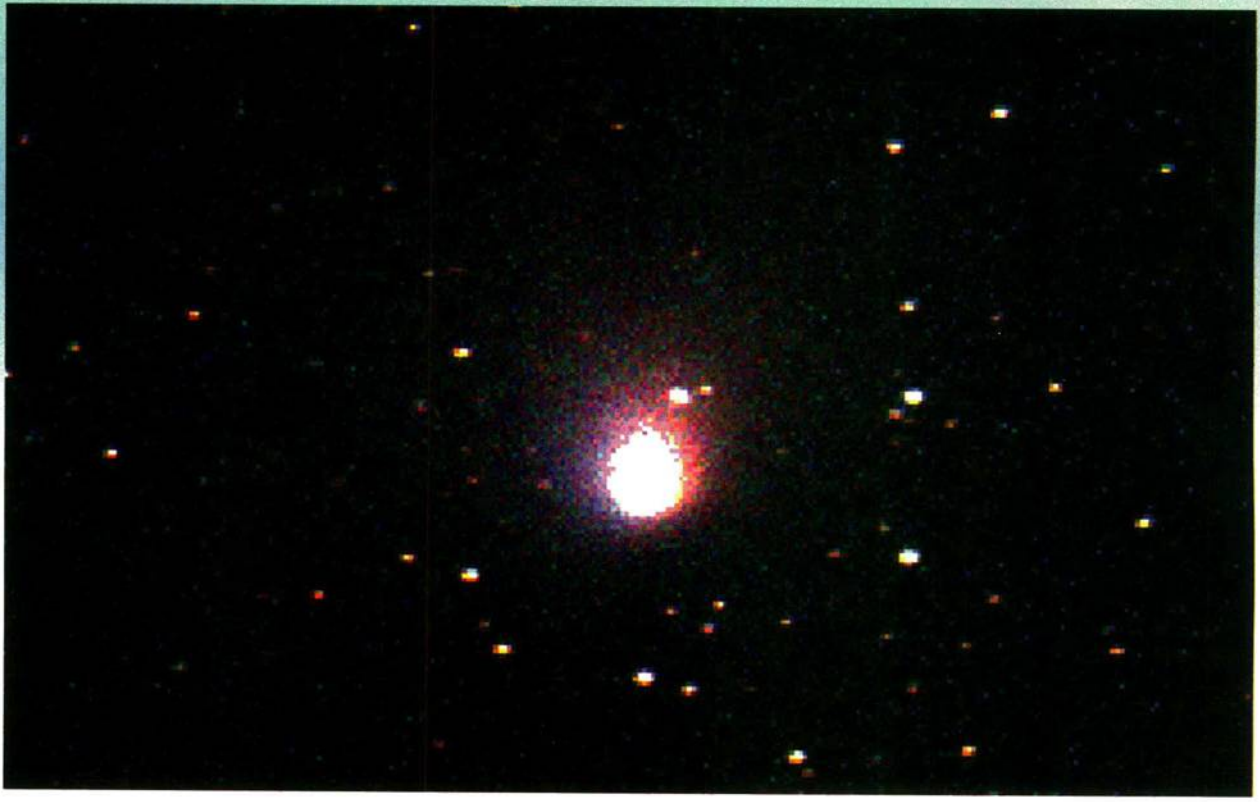
Orbital Elements for Hale-Bopp

Perihelion Time (T)	April 1.64155 1997
Perihelion Distance (q)	0.9130230 AU
Eccentricity (e)	0.9944413
Argument of Perihelion (ω)	130.66776°
Longitude of ascending node (Ω)	282.47292°
Inclination (i)	89.41422°

Hale-Bopp in May 1996

Pedro Ré

(14-inch SCT at f/6, Hi-Sis 22 CCD camera, 420-second exposure taken May 24, 1996)



Hale-Bopp in June 1996

Tim Puckett

(12-inch reflector at f/8, ST-6 CCD camera, tricolor composite made from 1-minute red, 2-minute green, and 3-minute blue exposures, taken June 10, 1996)

total magnitude rises from 5.0 on October 1 to 4.5 by month's end, making it equivalent to Halley's Comet at its best during the 1985–1986 apparition.

Take advantage of the dark of the Moon by viewing Hale-Bopp during the first half of the month. By the last days of October, the Moon will be past Full and will allow some dark sky viewing in the evening. Early in the month the comet is visible as darkness falls around 7:10 p.m. local time and sets by about 10 p.m. By October 15 darkness arrives by 6:50 p.m. and the comet remains visible until about 9:30 p.m. local time. During October the comet's distance from the Sun decreases from 430 million km to 376 million km; its distance from Earth increases from 447 million km to 457 million km.

November: Bright But Slipping Away . . .

November affords the final views of Hale-Bopp in 1996. And the windows for viewing the comet shorten, even as Hale-Bopp itself begins to brighten fairly impressively. The comet rises from magnitude 4.5 to 3.7, becoming a respectable naked-eye object that will probably sport a tail stretching several degrees. The comet's apparent northeastward motion on the sky accelerates during November, carrying it from near the globular cluster M14 to a point less than a degree south of another globular, this time 11th-magnitude NGC 6535 in Serpens Cauda, at month's end. At this time the comet will sit about 2° south of the prominent triangle of 4th-magnitude double stars formed by 67, 68, and 70 Serpentis.

As with the previous two months, the best viewing in November occurs during the first 15 days, before the distracting light of the Moon sneaks back into the evening sky. By the time darkness falls on November 1 at about 6:30 p.m., the comet is in view. It sets around 8:15 p.m. By the middle of the month the comet appears low in the west-southwest at dusk; the viewing window, at best, ranges from about 6:10 p.m. to 7:40 p.m. At this time Hale-Bopp will shine at about 4th magnitude. During November the comet's distance from the Sun decreases from 376 million km to 321 million km; its distance from Earth increases somewhat and then decreases to 437 million km.

Comet on Hiatus

With the first days of December comes the big rest. The positions of the comet and the Sun in the sky bring the two so close together that we cannot for a time see Hale-Bopp. Relegated to living from the memories of this first encounter, backyard astronomers will spend the first part of the winter in comet limbo. Only in February 1997 will Hale-Bopp reemerge into the morning sky and be visible against the stars of Aquila, Vulpecula, and Cygnus. There, in the glow of the Milky Way, the real show will begin. That we are treated to a mere warm-up this autumn that exceeds Halley is a testament to the high caliber of this spectacular comet. □

David J. Eicher is senior editor of ASTRONOMY. *He enjoys viewing comets with a battery of five instruments, from binoculars to a 17.5-inch reflector.*

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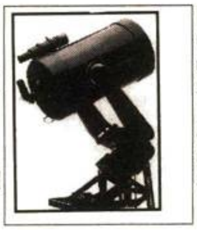

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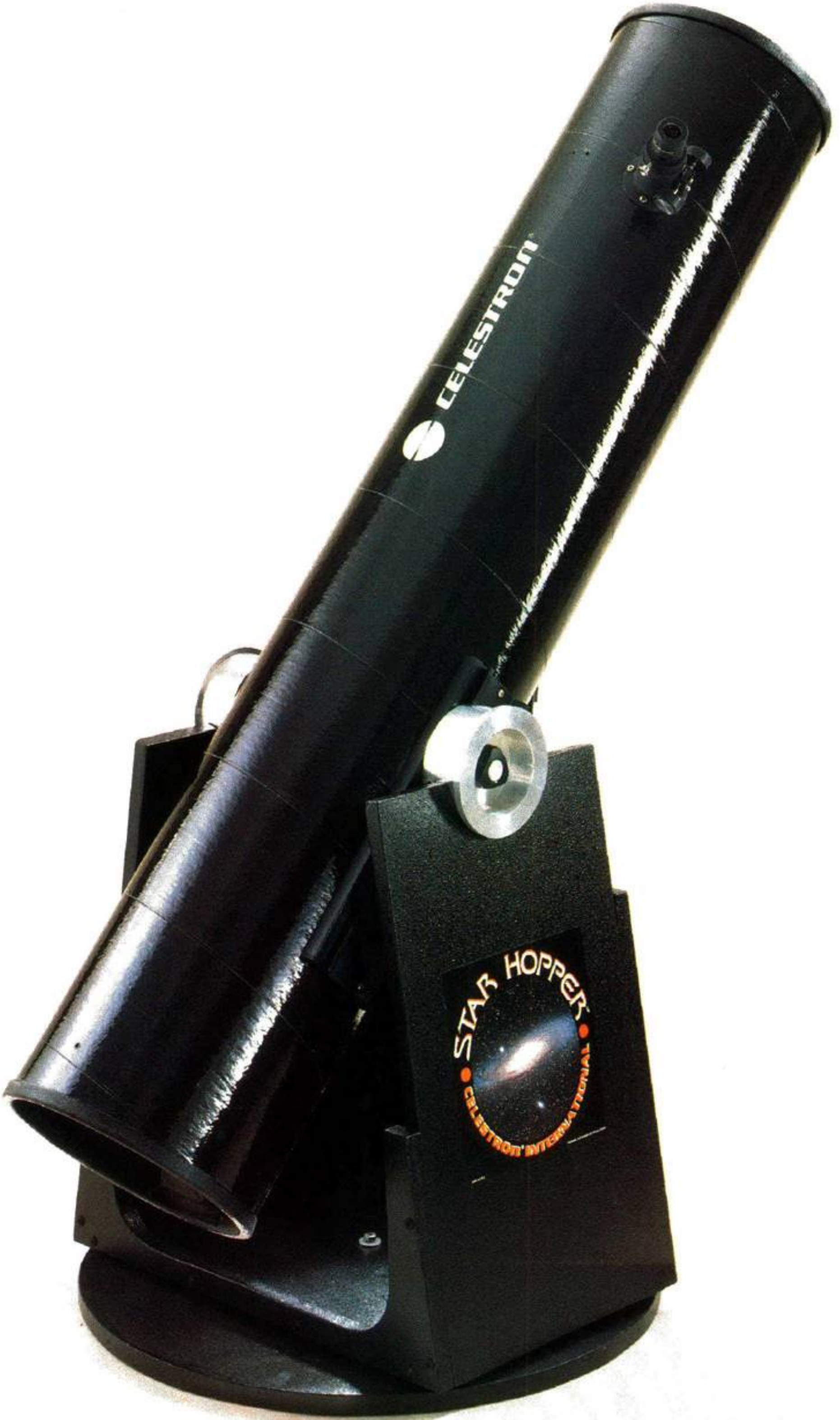
Celestron's entry into the Dobsonian market offers a scope with several unique features.

by John Shibley



Say "Celestron" and the first thing that comes to mind is the venerable Schmidt-Cassegrain telescope. Celestron's breakthrough in SCT manufacturing put a compact, medium-aperture scope well within the reach of the average observer's pocketbook. Now Celestron embraces another time-honored telescope design, the Dobsonian, that promises much the same flexibility.

The Dobsonian is quintessential "plug and play." Its alignment-free altazimuth mount and lower expense per aperture embodies just one goal: Observe for the least amount of effort and expense. Over the past 15 years, dozens of companies have weighed in with their own variations on the Dobsonian theme to create a loyal and well-supplied market.

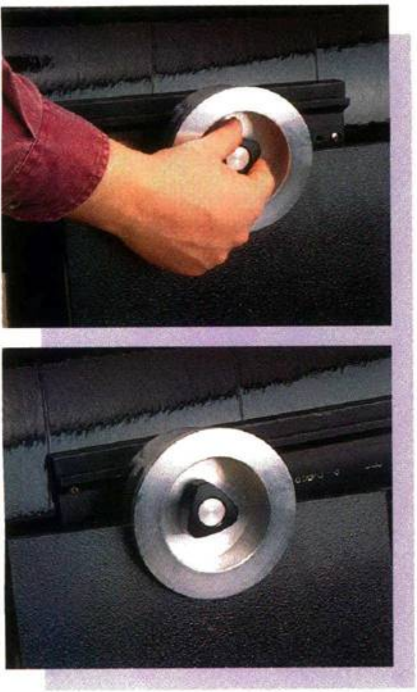
Celestron's entry into this field comes in the form of their Starhoppers: a 6-inch f/8 Dobsonian and an 8-inch f/6 Dobsonian. Each scope remains true to the Dobsonian "keep it simple" pedigree. But the Starhopper features innovations of its own worth noting, improvements on what was already elegantly simple.

Unpack and Play

The Starhopper 8-inch I tested ships in two boxes: a long, rectangular box that contains the optical tube and mirror, and a flat square box that holds the groundboard and disassembled rocker box.

The rocker box/groundboard unpacks in six pieces. Pre-drilled holes let you assemble the rocker box with sheet metal screws supplied by Celestron. The box then attaches to its groundboard with a

Celestron's Starhopper provides a number of user-friendly features not found elsewhere in budget-Dobsonian market.



All photos, ASTRONOMY: Jim Forbes

Starhopper's altitude bearing slides and locks along a dovetail track mounted on the tube. This lets you rebalance the optical tube after installing a heavier eyepiece and/or accessory.

bolt that also serves as the swivel/azimuth bearing. A layer of laminate on the rocker box's underside rides on six nylon groundboard glidestrips for ease of movement.

Meanwhile, the 52-inch optical tube comes snugged against a Styrofoam spacer that holds the mirror, two 4½-inch aluminum altitude bearings, and a 25mm modified achromatic eyepiece.

The optic comes mounted in its cell and unwraps from a protective layer of padding and tissue paper. The cell mounts into the bottom part of the tube assembly. You line up mounting holes in the mirror cell with holes drilled in the tube before screwing in three machine bolts.

Finally, its time to attach bearings that allow the scope to pitch up and down in altitude. The aluminum bearings slide into aluminum dovetail tracks mounted on either side of the tube, and then hand-tighten into place with plastic knobs.

This sliding-dovetail design is Celestron's answer to a problem that vexes Dobsonian owners every night they venture out under starry skies. A scope gets out of balance when heavier eyepieces or finders attach to the scope. Traditional fixes include moving counterweights up and down a track on the tube's other end.

In a refreshing development, Starhopper's design finally eliminates the need for loose weights. Just loosen each bearing's lockdown knob and rebalance the scope as it sits horizontally in the rocker box. When the scope achieves an even balance, retighten the knobs and observe. Do this every time you switch from a lighter eyepiece to one that is heavier, or vice versa.

First Light in the Field

Optically, the Starhopper worked like a champ under starry skies. My standard set of star tests yielded an image that held up quite well with exceptional contrast. Two hundred-plus-power showed clean, identical, well-resolved diffraction rings when the image was racked inside and outside of focus.

I did, however, notice an interesting optical effect while panning along the Milky Way with Starhopper. Stars at the telescope's magnitude limit seemed to dim down or wink out as I moved them from the center of the field of view to its edge.

This optical effect is due to uneven field illumination, and it comes from combining too tall a focuser with too small a secondary mirror. Under the very worst of circumstances, which does not apply to Starhopper's case, the center of the field of view looks markedly brighter than its edges.

This effect requires a little explanation. Light from a primary mirror doesn't really focus to a tiny point, as most two-dimensional light-path renderings might suggest. Rather, the cone of light forms a tiny, virtual image of the primary mirror that measures a substantial fraction of an inch in size.

When we apply different eyepieces, we scrutinize this virtual image at various magnifications. We insert the right eyepiece into an adjustable focuser to get a sharp, magnified view of the virtual image.

Here's where the interplay between the virtual image, a focuser's length, and the secondary mirror becomes important. The virtual image has to form close enough to the secondary mirror so its full extent gets light, or full illumination, from the entire primary mirror. If the virtual image forms a considerable distance away from the secondary mirror, only the image's central portion gets the primary mirror's total light output.

8-inch f/6 Starhopper Dobsonian

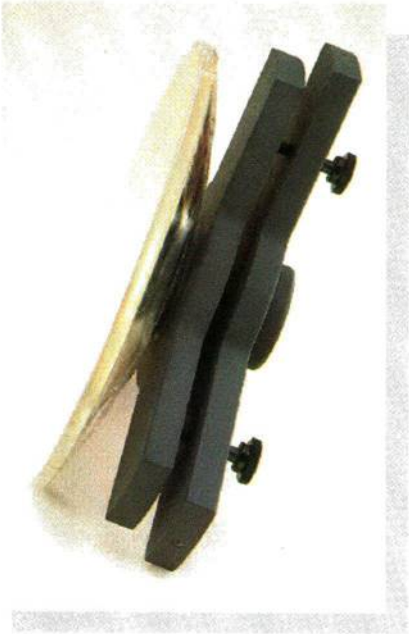
Standard Specifications

Aperture: 8 inches (203 mm)
Focal ratio: f/6
Focal length: 1218 mm
Length of tube: 52 1/2 inches
Size of focuser: 1.25-inch
Included 1.25-inch eyepiece: 25 mm (Modified achromatic, 49x)
Finder: optional
Secondary size (minor axis): 1.53 inches
Secondary obstruction (by diameter): 19%
Total telescope weight: 54 lbs.
Weight of heaviest component (tube): 29 lbs.
Eyepiece height at zenith: 48 inches
Suggested list price: $778
Typical retail price: $595 (Includes collimation tool, 0.965-inch eyepiece adapter, 25 mm eyepiece.)
Promised delivery date: Immediate

Optional Accessories

(Suggested list prices; actual prices vary with dealer)
6x30 finderscope: $68
Star Pointer reflex finder: $66
Astro Master digital setting circles: $598
Other Starhopper sizes:
4.5-inch: $378
6-inch: $578

Celestron International,
2835 Columbia Street,
Torrance, CA 90503
(310) 328-9560;
fax, (310) 212-5935.



The conical primary mirror (the same shape as a Schmidt-Cassegrain's primary mirror) cradles into the top plate of a two-plate aluminum cell.

To some extent, the Starhopper I tested suffers from this affliction, as do most commercial Dobsonians on the market. In Starhopper's case, you'd be hard-pressed to notice it under most observing regimens; nonetheless, I noticed it while panning the Milky Way.

All it would take to clear up this tiny effect would be to move the secondary mirror up the telescope tube an inch or so and install a shorter focuser. Perhaps Celestron could offer this option for the more discerning observer.

On the plus side, the existing secondary mirror blocks only 19% of the incoming light and mounts into a single-stalk secondary holder. A single stalk cuts down on scattered light and doesn't block as much of the incoming light path. More complex obstructions, like those found in a multivane secondary holder, lead to excessive diffraction and scattering of light, which in turn degrade image contrast and clarity.

Three equally spaced nylon thumbscrews adjust the secondary mirror's collimation, or optical alignment. I was especially gratified to see these collimation screws didn't need tools like an allen wrench or phillips screw driver for adjustment. The heads could be larger, however; making adjustments while wearing gloves was difficult.

Mirror and the Mechanics

Starhopper's primary mirror has certainly one of the more unusual shapes I've come across. Its rounded, conical underside form cuts down on weight while maintaining rigidity, supposedly to a better degree than most traditional "thin" mirrors.

The Pyrex mirror's conical shape also aids in cooling (or heating) the optic to ambient temperature. When compared to traditional, flat-bottomed mirrors, the rounded shape exposes a greater surface area of glass for more efficient heat transfer. An optional cooling fan mounts behind the mirror to speed this cool-down process as well. The mirror's shape also holds down image-distorting turbulence as air rises from the bottom of the tube towards the front opening during cooling.

The mirror's conical backside center-mounts into a two-plate aluminum mirror cell. Everything's held in place by a retaining bolt that runs through both plates into the rear of the mirror. This attach point also doubles as a pivot point during collimation.

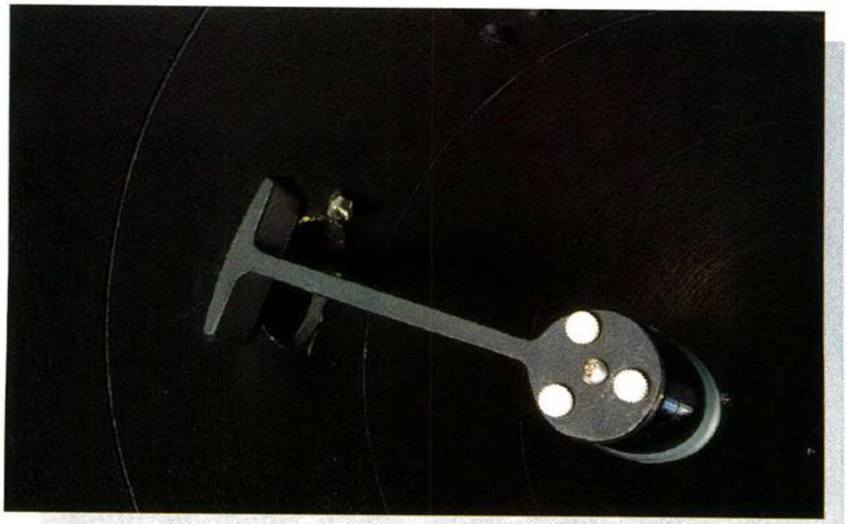
Collimation knobs lie at each of the bottom plate's three corners. They snug up against the second plate that cradles the main mirror. Each knob twists to angle the second plate in an appropriate direction. Banking the attached mirror in this fashion collimates the optics.

In what I consider a nod to ergonomic design, each oversized collimation knob turns by hand, with no tools required. Adjustments are firm and sure. Celestron even throws in a simple but effective optical collimation tool to help you achieve alignment perfection. Once the mirror is adjusted, the beefy cell doesn't shift in the least, even after several rough and tumble trips on a car's back seat.

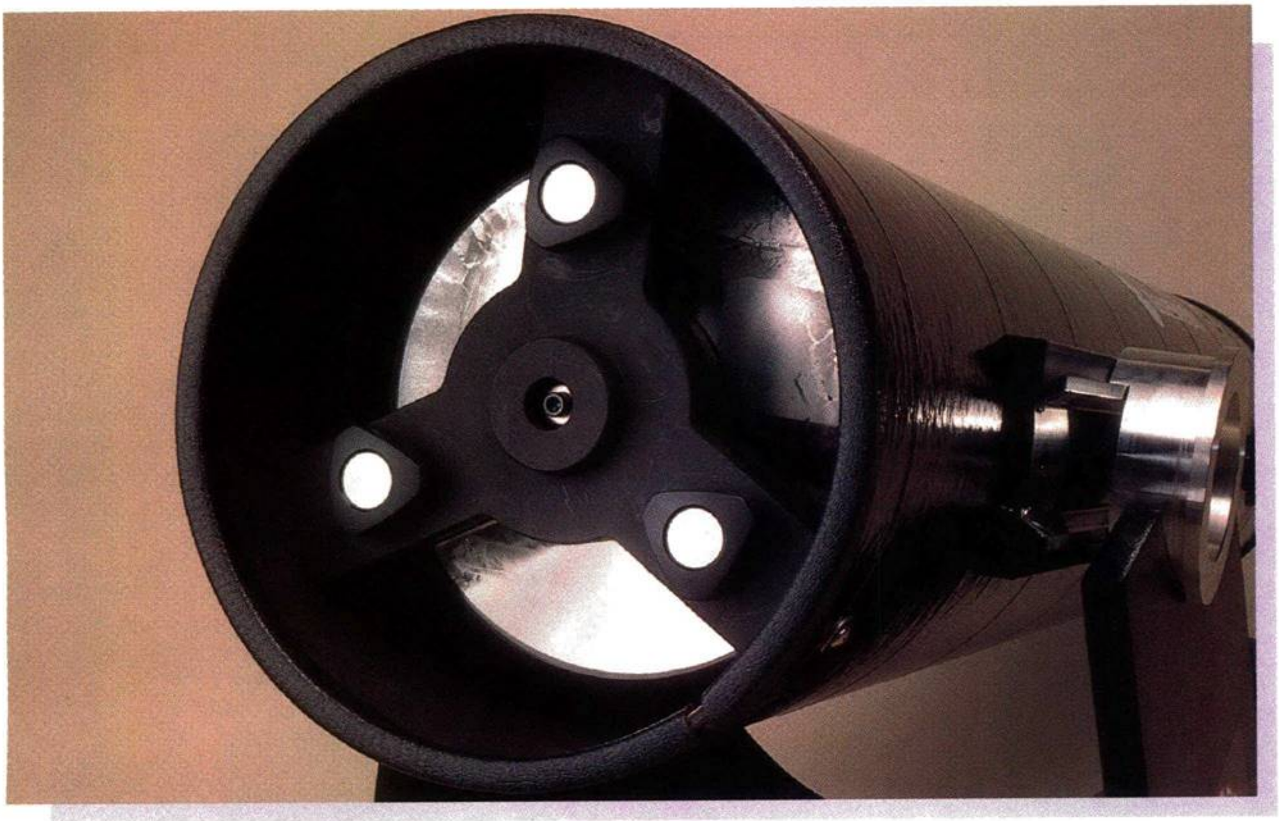
Mechanically, the Starhopper's sliding-bearing system worked like a breeze in the field. There where, however, a couple of minor snafus with the rocker box and groundboard worth mentioning here.

Some of the screws that held together the rocker box loosened up after several observing sessions' worth of panning the scope around in azimuth. While this in no way compromised the box's integrity, the loosened joints affected the scope's ability to dampen out the jiggles seen in an eyepiece after panning. To keep this from happening, you might want to apply wood glue where the pieces join before screwing them together.

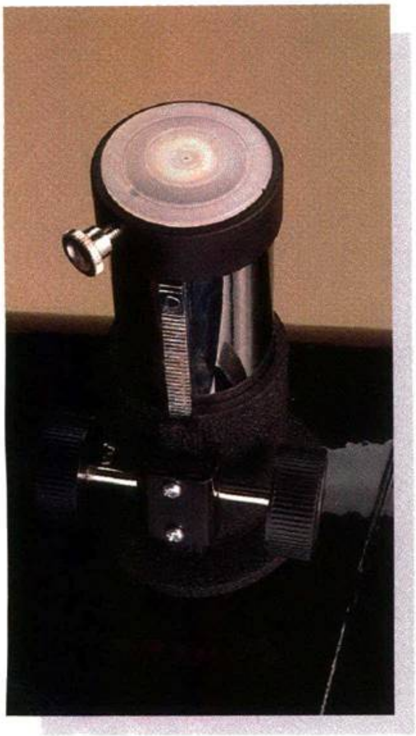
Another slight shortcoming was in the groundboard. Its underside is flat, so any slight unevenness or stone on the



A single-stalk secondary mirror blocks and diffracts less incoming light. Nylon thumbnuts let you collimate the secondary mirror if needed.



Starhopper's oversized collimation knobs let you field-adjust optics with ease. There's also plenty of room for a ventilation fan to more quickly cool down the primary mirror.



A sturdy focuser accepts 1¼-inch eyepieces and racks through 2¾ inches of travel. Celestron also includes a collimation tool and an adapter that accepts 0.965 eyepieces.

ground made the scope wobble during panning. Some well-placed feet, perhaps a set of four blocks, might serve to elevate the board and eliminate this problem.

I found the groundboard's thin bearing tape, against which a plastic laminate on the rocker box's underside rides, was barely adequate for smooth motion in azimuth. Pivoting from side-to-side seemed unduly stiff. Sometimes the rocker box's base even scraped against the groundboard, especially if the scope wasn't placed on absolutely flat ground.

A quick trip to the hardware store for some Teflon furniture glides, followed by five minutes of installation, soon fixed this problem. The pre-installed bearing tape was usable, but the glides I installed helped smooth out azimuth motion considerably.

Both the groundboard and rocker box components are made of compressed particle board, finished with a textured, glossy black paint. This surface was especially durable against wear and tear and resisted the prodigious dew Wisconsin evenings are capable of producing.

The telescope's spiral-wound sonatube also held up well to field conditions. Its outer vinyl layer resisted scuffs and scrapes. Plastic rings protected each of the tube's ends from wear and tear.

One Step Closer to an Ideal

Minor concerns aside, Starhopper is a milestone on the road towards a better commercial Dobsonian. Fifteen years ago, you couldn't find a scope of Starhopper's friendliness, usability, and overall quality for what amounts to an average American worker's one-week wage.

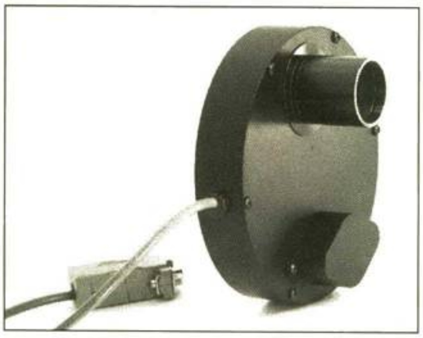
Starhopper's innovative mirror, mirror cell, and adjustable altitude bearings, combined with its crisp, sharp images more than meet what every Dobsonian owner hopes to have in an easy-to-use, backyard telescope. And with 12- and 20-inch versions rumored poised to enter the market early next year, the Starhopper line will soon break into the big-aperture league. □

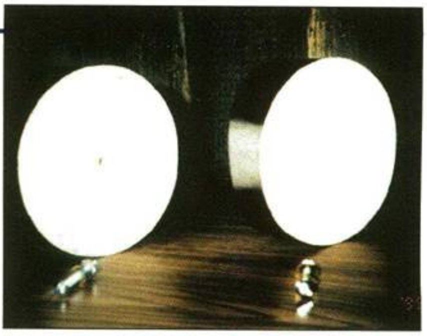
NEW PRODUCTS

CCD Color Filter Wheel

The Model CFW-8 color filter wheel works with any SBIG CCD camera to take tricolor images. The wheel is controlled from the computer keyboard and utilizes a stepper motor system with a positional accuracy of 0.1 inch. Images are shot through built-in red (spectral response: 585-680 nm), green (696-585 nm) and blue (<380-502 nm) filters. Two other filters, a clear and an in-line infrared blocking, come loaded on the wheel. The CFW-8 attaches to a CCD through a male-male T-thread coupler, or with its standard 1¼-inch nosepiece. It also connects to an SCT telescope using a T-thread visual back, or directly with a 1¼-inch or 2-inch nosepiece.

Santa Barbara Instruments Group, 1482 East Valley Road, Suite #33, Santa Barbara, CA 93108; (805) 969-1851; fax, (805) 969-4069. The Model CFW-8 Color Filter Wheel: $650.





Dobsonian Bearings

Teltek offers telescope makers ready-made altitude bearing circles that fit 8-, 10-, and 12-inch Dobsonian telescopes. Each bearing is made from hardwood maple. The concave side bolts against the tube on felt pads using fasteners included with the kit. The outside face is sealed and unpainted. A layer of graphite epoxy forms the bearing's surface. Custom sizes cost marginally more.

Gregg Michalak c/o Teltek, Box 745, Pine Bush, NY 12566; (914) 744-5556; fax, (914) 744-2427. Bearing circles for 8- and 10-inch telescope tubes: $25 per pair; For 10-inch telescopes: $30 per pair. Add $5 postage and handling.

CELESTRON
Barlow Lens 2x
Model #93507

Compact Barlow Lens

Celestron now markets a compact 2x Barlow lens for 1¼-inch eyepieces that's 3" long and weighs 4 oz. The lens features apochromatic, fully-coated optics for high-contrast, false-color-free views. It also has a 27mm clear aperture for better eye relief. A rubber grip on the barrel makes for easier handling in cold weather.

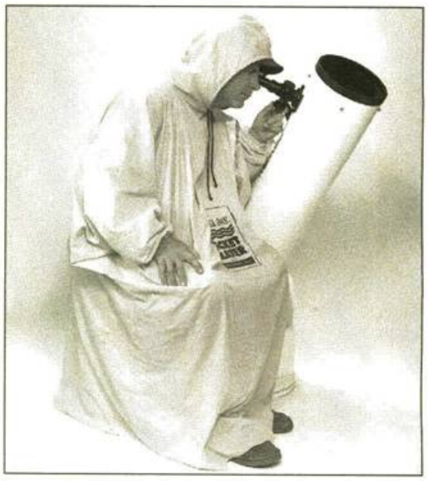
Celestron International, 2835 Columbia Street, Torrance, CA 90503; (310) 328-9560; fax, (310) 212-5835. 2x Barlow lens, model # 93507: $78 (list price).

New Products presents announcements issued by manufacturers. ASTRONOMY *assumes no responsibility for the product information supplied. Prices are suggested retail. Suppliers should send announcements and color photographs to the attention of John Shibley, P.O. Box 1612, Waukesha, WI 53187, or newprod@astronomy.com.*

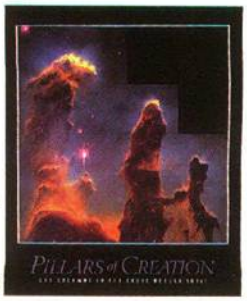
Heated Observer System

The Jenrick Marketing Group takes a time-tested idea from Minnesota ice fishing and brings it into the world of amateur astronomy. They start with a propane heater that generates warmth for up to 20 hours and house it in a six-gallon bucket with a padded seat. Next, they add a ripstop nylon poncho to get what's called the All Night Bucket Heater/Portable Heating System. You wear the water-resistant poncho to trap warmth from the bucket seat. In this way, you become your own heated room. Ponchos come in brown, hunter's orange, and white.

Jenrick Marketing Group, 21090 Olinda Trail, Scandia, MN 55073; (800) 910-4409 or (612) 433-4943; fax, (612) 433-3093. The All Night Bucket Heater/Portable Heating System: $93.95.



Pillars of Creation Poster



Hansen Planetarium reproduces the Hubble Space Telescope's stunning photo of M16, the Eagle Nebula, on a 24" x 30" poster. The image show pillars of molecular hydrogen being eroded away by nearby young, energetic stars. Close examination reveals the stellar winds are uncovering embryonic solar systems. The poster comes in paper or laminated versions. Both ship with a fact sheet.

Hansen Planetarium Publications, 1845 South 300 West #A, Salt Lake City, UT 84115-1804; (800) 321-2369 or (801) 483-5400. Pillars of Creation poster (stock #51-5): $10 (paper), $20 (laminated), plus $4.75 shipping and handling.

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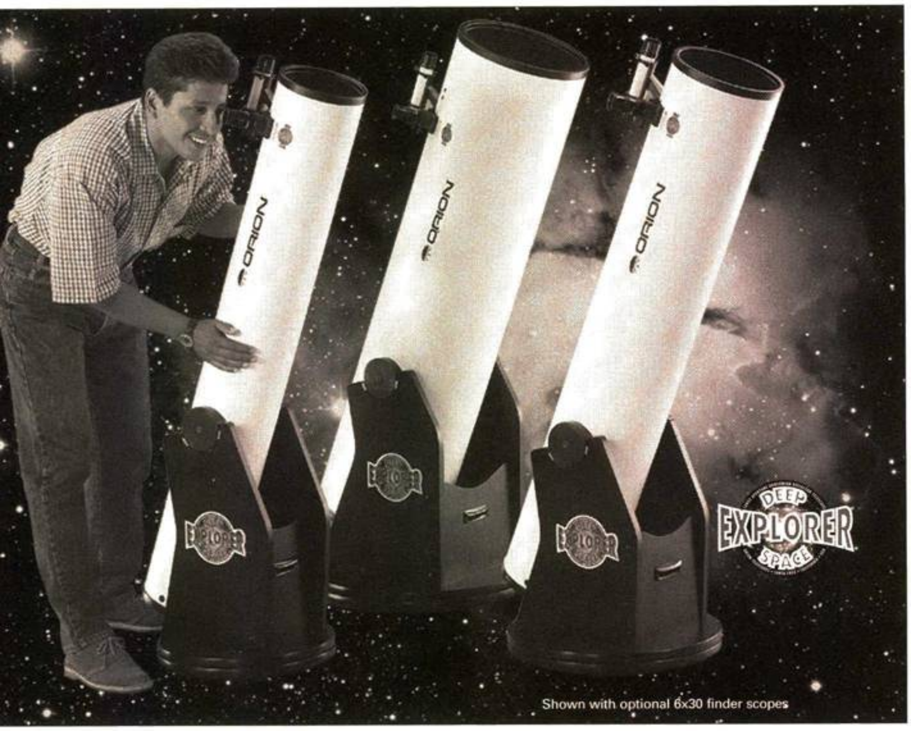

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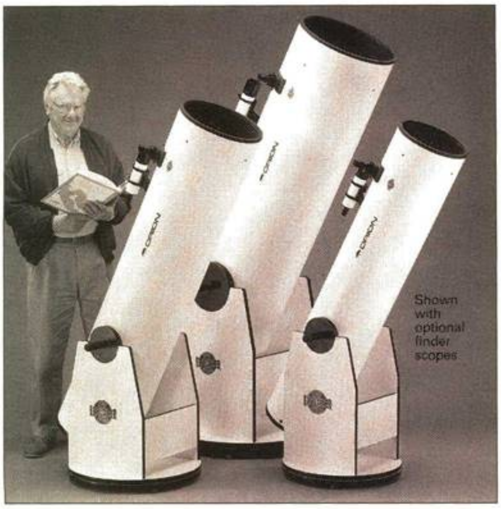

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7.5mm	*Mfr's List $136*	~~$78~~	#8672	**$68**	(3.45)
12.5mm	*Mfr's List $146*	~~$83~~	#8673	**$73**	(3.45)
18mm	*Mfr's List $160*	~~$93~~	#8674	**$83**	(3.45)
24mm	*Mfr's List $176*	~~$99~~	#8677	**$89**	(3.45)
30mm	*Mfr's List $182*	~~$106~~	#8678	**$96**	(3.67)
35mm	*Mfr's List $210*		#8679	**$119**	(3.67)
42mm	*Mfr's List $210*		#8680	**$127**	(3.67)

Orion 5-Element Ultrascopic™ Eyepieces

With Superb, High-Performance Ultra™ Multi-Coatings!

Reduced Up To $20!

Ultrascopic eyepieces yield the highest contrast, greatest light transmission, and best overall image fidelity obtainable. With a superior 5-element design and Ultra™ Multi-Coatings on every surface, they outperform 4-element eyepiece designs. Wide 52° field of view. Removable contoured rubber eyeguard. The 5mm and 3.8mm feature advanced 7-element designs with surprisingly long eye relief. Guaranteed to knock your socks off!

Medium-High Power 5-Element 1.25"
20mm #8566, **15mm** #8568, **10mm** #8570, **7.5mm** #8572
~~$89~~ **$79 each** (3.45)

Wide-Field 5-Element 1.25"

25mm Ultrascopic	~~$99~~	#8564	**$89**	(3.45)
30mm Ultrascopic		#8562	**$119**	(3.45)
35mm Ultrascopic		#8560	**$139**	(3.45)

High-Power 7-Element Long Eye Relief 1.25"

5mm Ultrascopic	~~$109~~	#8574	**$89**	(3.45)
3.8mm Ultrascopic	~~$109~~	#8576	**$89**	(3.45)

ORION Sirius™

Quality Plössl 1.25" Eyepieces

Fantastic Fully Coated Eyepieces at an Incredibly Low Price!

You could pay nearly twice the price for "famous name" Plössl eyepieces, but why? Sirius Plössls are top-quality, 50° apparent-field (43° 40mm) eyepieces that yield extremely sharp images of impressively high contrast. Ideal for all types of telescopes. The classic 4-element Plössl design is renowned for its fantastic performance. The Sirius Plössl's fully-coated optics are mounted in black-anodized aluminum housings with chrome-plated brass barrels for durability and precision fit. Available in 1.25" barrels only.

7.5mm #8738, **10mm** #8736, **12.5mm** #8726, **17mm** #8734, **20mm** #8733, **26mm** #8732
$49.95 each (3.45)

32mm #8728, **40mm** #8730 **$59.95 each** (3.67)

SPECIAL OFFER!

Get a FREE Orion Eyepiece & Accessory Case with the purchase of any four or more Orion Sirius Plössl eyepieces! A $19.95 value!

Dimensions: 11"x7"x3". For description, see eyepiece cases below. Offer expires Dec. 31, 1996.

Illuminated Reticle Eyepieces

Great for astrophoto guiding, polar alignment, and other uses.
All models illuminated with a night-vision red LED.

12mm Kellner 1.25"
Double crossline reticle, fixed brightness. Plugs into power panel drive bases.
#8482 **$79.95** (3.45)

12mm Kellner Wireless 1.25"
Same as #8482 except wireless. Needs two SR-44, batteries, not included.
#8481 **$99** (3.45)

12.5mm Plössl Wireless 1.25"
With fully adjustable brightness control. Double crossline reticle. Batteries included.
#8484 **$139** (3.45)

9mm Orthoscopic Wireless 1.25"
Bull's-eye within crosshairs, adjustable brightness. Needs two SR-44 batteries, not included.
#8488 **$159** (3.67)

Orion Barlow Lenses

Double or even triple the power of your eyepieces, maximizing the versatility of your collection. Available in .965", 1.25", and 2" diameters.

Fully Baffled 2x Barlow
Multi-coated, with internal baffling to block transmission of stray light. Premium performance at a remarkable price.

.965" 2x Barlow	#8740	**$39.95**	(2.98)
1.25" 2x Barlow	#8746	**$49.95**	(2.98)
2" 2x Barlow	#8724	**$89.95**	(3.95)

VariPower 2x–3x Barlow
Our most versatile barlow. Adjusts to any magnification between 2x and 3x. Fully multi-coated optics. 1.25" barrel.
#8748 **$69.95** (3.45)

Shorty™ Barlows
About half the length of our regular barlows for added convenience. Magnifies 2x or 3x when positioned behind or in front of diagonal, respectively, on a refractor or Schmidt-Cassegrain. Works in all scopes, including those in which longer barlows won't work.

.965" Shorty Barlow	#8710	**$49.95**	(2.98)
1.25" Shorty Barlow	#8711	**$49.95**	(3.45)

TELESCOPE COVERS AND TOTE BAGS

All our scope totes and covers are made of rugged, water-resistant nylon, and are heavily stitched to last.

Soft Scope Cases

These heavily foam-padded carrying cases are real space-savers! Zipper access, with accessory pouch (SC models only) and strap handles.

For SkyView 90mm	#15146	**$98**	(4.45)
For SkyView 4.5"	#15148	**$98**	(4.45)
For Celestron C5 & Meade 2045D	#15142	**$109**	(4.45)
For Celestron, Meade 8" (not LX)	#15141	**$139**	(4.98)
For Meade 8" LX200, LX100, LX50	#15144	**$149**	(4.98)

Dobsonian Tote Bags

Holds Orion Deep Space Explorer tubes. May also fit some home-built Dobsonians. Nylon drawstring closure. Black nylon shoulder straps.

6" DSE Bag	10"x10"x60"	#15150	**$49.95**	(3.41)
8" DSE Bag	12"x12"x62"	#15151	**$54.95**	(3.41)
10" DSE Bag	14"x14"x68"	#15152	**$64.95**	(3.54)

Tripod & Wedge Bags

Designed to hold Schmidt-Cassegrain tripods & wedges. Handy carry straps.

Economy Tote and Storage Bag
Inexpensive reinforced tote bag without padding. Zippered pocket, nylon drawstring. Length 4' 2", width 1' 5".
#15095 **$34.95** (3.41)

Lightweight Tripod Bag
Fits the Celestron lightweight tripod for C5 and C8+ telescopes (without the wedge). Zippered closure. Inside pocket.
#15143 **$43.95** (3.26)

Field Tripod and Wedge Bag
For Celestron or Meade standard tripod and wedge combinations (not Meade Superwedge or Celestron Ultima wedge). No need to remove the wedge from tripod. Length 4' 2", width 1' 10".
#15096 **$79.95** (5.19)

Deluxe Tripod and Wedge Bag
Fits Ultima tripod with wedge attached.
#15140 **$109** (5.19)

Scope Caps for Deep Space Explorers

Water-resistant soft nylon cap, may also fit other comparably sized Newtonian tubes such as Meade Starfinder.

For 6" DSE	#15180	**$6.50**	(2.19)
For 8" DSE	#15181	**$8.95**	(2.19)
For 10" DSE	#15182	**$10.95**	(2.19)
For 12.5" DSE	#15183	**$14.95**	(2.19)
For 16" DSE	#15184	**$18.95**	(2.19)

Scope Saver™ Telescope Covers

Water-resistant blue nylon hood protects your scope from the elements. Nylon drawstring closure with cord lock.

For Dobsonian Telescopes. Covers entire tube and base. Great for keeping it covered while not in use, or during transport. Fits Standard or Premium Deep Space Explorers, Newtonian tube assemblies, or home-built telescopes.

6" Standard	9"x12"x54"	#15135	**$34.95**	(2.43)
8" Standard	10"x14"x54"	#15136	**$39.95**	(2.43)
10" Standard	12"x14"x55"	#15137	**$50.95**	(2.43)
10" Premium	12"x12"x64"	#15154	**$59.95**	(4.98)
12.5" Premium	17"x17"x74"	#15155	**$69.95**	(3.54)
16" Premium	20"x20"x84"	#15156	**$96.95**	(4.45)

For SCs and Small Equatorial Telescopes. Fits over the optical tube either on or off the tripod.

8" SC Model Fits any Celestron or Meade 8" Schmidt-Cassegrain telescope. 10"x12"x34"
#15130 **$33.95** (2.43)

10"–11" SC Model Fits Meade 10", Celestron Ultima 11" (not original C-11), and Celestron CG-11 telescopes. 14"x16"x44"
#15131 **$39.95** (2.43)

4.5"–6" Model Fits 4.5" to 6" Newtonian reflectors, such as SkyView 4.5, Celestron 4.5, C6. 6"x22"x38"
#15134 **$37.95** (2.43)

OBSERVING AIDS

Orion FlexiShield™ Dew Caps

Fights moisture buildup. Flexible black material fits snugly around scope tube; Velcro fastener. Rolls up or flattens for convenient storage and travel. Models to fit most telescopes.

8" Celestron/Meade SC	#4200	**$44.95**	(2.98)
9-1/4" Celestron SC	#4214	**$48.95**	(2.98)
10" Meade SC	#4201	**$54.95**	(2.98)

Other sizes available for scopes 3.5" to 14". See our free catalog for details.

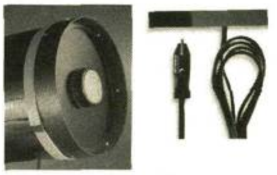
Eyepiece & Accessory Cases

With patented unbreakable latches, die-cut foam inserts. (Inside dimensions shown)

Small Case (shown) 11"x7"x3"
#5951 **$19.95** (2.78)

Medium Case 12.5"x9"x5"
#5952 **$27.95** (3.36)

Large Case 16"x11"x5"
#5953 **$42.50** (5.19)



Orion Dew Zapper™

Gently warms perimeter of corrector plate, eliminating dew buildup without "heat wave" disturbances.

8" Dew Zapper fits Meade & Celestron 8" SCs
DC #3503, AC #3504 **$47.95** (2.98)

10" Dew Zapper fits all Meade 10" SCs
DC #3506, AC #3508 **$54.95** (2.98)

11" Dew Zapper fits all Celestron 11" SCs
DC #3510, AC #3512 **$59.95** (2.98)

NEW!

Orion RedBeam™ LED Flashlight

Astronomically correct red LED preserves dark adaptation. Shock-proof yellow plastic body is easy to find in the dark. Two AA batteries INCLUDED.
#5744 **$11.95** (2.98)

Many more flashlights in our catalog!

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BINOCULARS

SALE!

Orion 50mm Vista™

A top-quality astronomical binocular, the Vista features BAK-4 prisms and fully multi-coated optics for high-fidelity images. Long 16mm eye relief and roll-back eyecups for eyeglass wearers. Weighs just 28 oz. Includes hard carrying case.

7x50 6.0° field of view	#9355	**$258**	(5.19)
10x50 5.3° field of view	#9353	**$258**	(5.19)

Orion 50mm Explorer™

High-performance, economical binoculars with BAK-4 prisms and multi-coatings. Great for both stargazing and daytime viewing. Rubber body coating for sure grip. Includes case, neck strap, and lens caps.

7x50 6.8° field of view	#9306	**$147**	(4.44)
10x50 5.3° field of view	#9308	**$147**	(4.44)

Celestron 8x56, 9x63 Ultima

Scanning the night sky is a treat with these large-aperture binos. fully multi-coated, BAK-4 prisms, and long 21mm eye relief. Tripod adaptable. Case and wide neck strap included.

8x56 6.1° field of view	~~$349~~ #9596	**$279**	(5.71)
9x63 5.4° field of view	#9542	**$329**	(5.71)

Orion 50mm UltraView™

The perfect binocular for eye- and sunglass wearers. Extra-long 23mm eye relief and unique pop-down eyepiece guard. Fully multi-coated optics for high light transmission and maximum contrast. BAK-4 prisms. Close focus 16'. Weighs 32 oz. Includes soft nylon case, eyepiece rain shield, and neck strap.

7x50 6.5° field of view	#9357	**$188**	(4.95)
10x50 6.5° field of view	#9351	**$188**	(4.95)

Catch Comet Hale-Bopp!

Hale-Bopp promises to put on a spectacular show in 1997, but you can view it right now in binoculars. Our Little Giant™, Giant, or SuperGiant™ binos are just the ticket!

Orion 70mm Little Giants™

The standard for hand-holdable high-power astronomy binoculars. Fully multi-coated. Terrific brightness and edge sharpness! Weighs only 68 oz. Includes tripod mounting adapter and deluxe hard case.

10x70 #9501, **14x70** #9494 **$369** (6.97)

Orion 80mm Giant Binoculars

For jaw-dropping views of the heavens and Earth, our wide-aperture Giants can't be beat. Fully multi-coated optics and BAK-4 prisms provide fantastic contrast and edge sharpness. 20% more light transmission than "fully-coated." Includes deluxe hard case with handle and shoulder straps.

11x80 Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable.
#9502 **$469** (8.05)

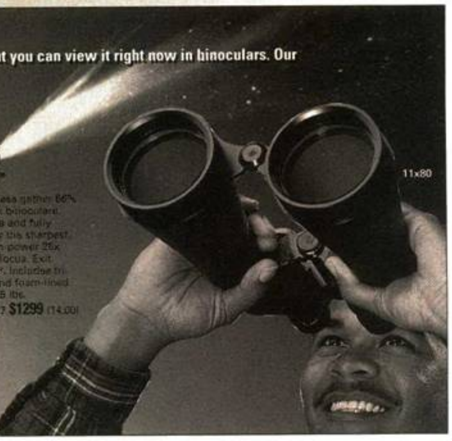
16x80 Excellent for astronomy and daytime observation.Tripod recommended.
#9496 **$469** (8.05)

20x80 Highest-power model, perfect for smaller deep-space objects and long-range daytime views. Tripod required.
#9498 **$469** (8.05)

Orion 25x100 SuperGiants™

Gigantic, nearly 4" lenses gather 66% more light than 80mm binoculars. Features BAK-4 prisms and fully multi-coated optics for the sharpest, brightest images. High-power 25x magnification; center focus. Exit pupil 4.0mm, field 2.6°. Includes tripod mounting plate and foam-lined metal case. Weighs 7.5 lbs.

#9497 **$1299** (14.00)



QUALITY COMPONENTS

6x30 Achromatic Finder Scopes

6x30mm Straight Includes 2-ring metal bracket, fits scopes 6"–12".
#13023 (white)
$49.95 (3.41)

6x30mm Right-Angle With prism diagonal for right-angle viewing. Includes bracket.
#13021 (white)
$84.95 (3.41)

Large-Aperture Finder Scopes

High-quality finders at very reasonable prices! Wider apertures for brighter views. Fully coated achromatic optics with adjustable focus. Precision crosshairs. White or black enameled metal tube. (Mounts sold separately.)

8x50mm Bright 6.25mm exit pupil.
#7090 (white) #7094 (black) **$79.95** (3.41)

8x50mm Illuminated Wireless illuminator with adjustable brightness.
#7092 (white) #7096 (black) **$119** (3.41)

9x60mm 44% more light grasp than 50mm models.
#7091 (white) #7095 (black) **$119** (3.41)

9x60mm Illuminated Wireless illuminator with adjustable brightness.
#7093 (white) #7097 (black) **$159** (3.41)

Low-Profile Helical Focusers

Economical yet precise focusing. Ideal for fast optical systems. Cast aluminum base with threaded, machined aluminum inner tube.

1.25" Helical Focusers	#13014	**$39.95**	(2.45)
2" Helical Focusers	#13016	**$59.95**	(2.98)

Rack-and-Pinion Focusers

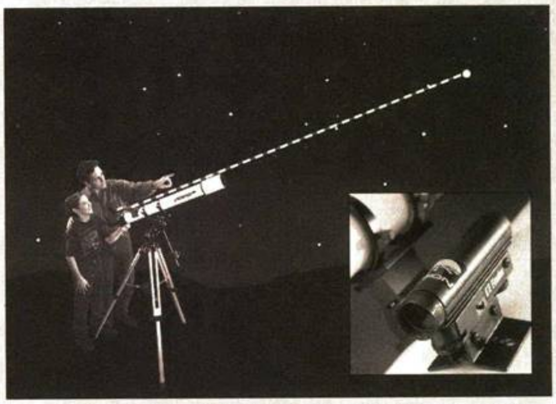
Finest in their class! Diagonal-cut plated brass racks, oversized knurled knobs, long-focus travel.

1.25"	#13007	**$69.95**	(2.98)
2" includes 1.25" adapter	#13003	**$119**	(3.95)

Dovetail Mounts for 50mm and 60mm Finder Scopes

Instantly install or remove your finder, without tools, without disturbing alignment! Black-anodized aluminum fits any scope 6" or larger including Celestron and Meade Schmidt-Cassegrains.

8x50mm Dovetail Mount	#5040	**$39.95**	(2.45)
9x60mm Dovetail Mount	#5041	**$47.95**	(2.98)
Extra Dovetail Mount Base	#5050	**$14.95**	(2.19)



Orion EZ Finder™ Reflex Sight

This nifty device makes pointing a telescope almost as easy as pointing your finger. Keep both eyes open and look through EZ Finder, and you'll see the image of a red dot projected at infinity, showing exactly where the telescope is aimed in the sky. Installs on any telescope in minutes. Wide 10° field of view, low and high brightness settings. Fits Meade and Celestron Schmidt-Cassegrain scopes in existing mounting holes; attaches easily to other scopes. Weighs just 2.5 oz.

#7075 **$49.95** (3.45)

Parabolic Primary Mirrors

Excellent hand-figured parabolic mirrors guaranteed to meet theoretical limits of resolution. Fine-polished, coated twice: with aluminum and silicon monoxide. Very competitively priced!

Standard Primary Mirrors
Fine soda-lime plate glass, 1:8 thickness ratio. Guaranteed ±1/8 wave. Sizes: 4.5" f/10, 6" f/8, 8" f/6, 10" f/4.5, 10" f/5.6, 12.5" f/4.8. Call for pricing.

Pyrex Low-Expansion Mirrors
Fine annealed Pyrex brand low-expansion glass, 1:6 thickness ratio. ±1/10 wave. Available with standard or 94% reflectivity, enhanced aluminum coatings. Sizes: 6" f/5, 6" f/8, 8" f/6, 10" f/4.5, 10" f/6, 12.5" f/6, 16" f/4.5. Call for pricing.

Elliptical Secondary Mirrors

Fine annealed Pyrex brand glass, aluminized and SiO overcoated. ±1/10 wave accuracy. Available with standard- or high-reflectivity enhanced aluminum coatings. Ten sizes from 0.75" to 4.00" minor axis. Call for pricing.

Astrositall Zero-Expansion Mirrors

Astrositall is a glass-ceramic material with an ultra-low coefficient of thermal expansion. Ideal for harsh environmental conditions. 1:7 thickness ratio. ±1/10 wave surface accuracy. Enhanced aluminum coatings.

Astrositall Parabolic Mirrors 6" f/8, 6" f/5, 8" f/6, 10",f/6

Astrositall Elliptical Flat Mirrors 1.30", 1.52", 1.83", 2.14". Call for pricing.

We also carry Sonotube Newtonian optical tubes, Dob altitude bearings, mirror cells, and other telescope components. See our catalog.

ACCESSORIES

Many More Accessories in Our 100-Page Color Catalog!

Universal Camera Adapters

For prime focus or eyepiece projection astrophotography.

.965"	#5268	**$29.95**	(2.98)
1.25"	#5264	**$29.95**	(2.98)
Hybrid 1.25"/.965"	#8782	**$29.95**	(2.98)

Variable-Power Camera Adapter

Allows variable projection distances during eyepiece projection photography. For 1.25"eyepiece holders.

#5262 **$39.95** (2.98)

Orion Slow-Motion Adapter

Attaches to your photo tripod pan head. Two slow-motion control knobs to make precision adjustments in altitude and azimuth. Very handy for tracking planets, the Moon, and constellations with refractor telescopes and small spotting scopes. Attaches with a standard 1/4-20 thread.

#7033 **$39.95** (2.19)

Tele-Extenders for Schmidt-Cassegrain Scopes

For high-powered photography with your Meade or Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender	#5125	**$29.95**	(2.98)
Variable Tele-Extender	#5127	**$39.95**	(2.98)

T-Adapters for SC and MAK

Threads to rear cell of telescope, requires T-ring for your camera model.

For SC	#5116	**$26.95**	(2.98)
For C90	#7115	**$34.95**	(2.98)

T-Rings for 35mm Cameras

Available for many different camera types; call toll-free or see our catalog for your particular model.

45° Correct-Image Diagonal Prisms

Ideal for all refractors and compound telescopes used for terrestrial viewing.

.965" Diagonal	#8791
1.25" Diagonal	#8790
Hybrid 1.25"/.965"	#8792

$44.95 each (3.45)

90° Star Diagonal Prisms

Orion's multi-coated diagonals are ideal for refractors and Schmidt-Cassegrains.

.965" Star Diagonal	#8761	**$29.95**	(2.98)
1.25" Star Diagonal	#8763	**$39.95**	(2.98)
Hybrid 1.25"/.965"	#14008	**$39.95**	(2.98)

Orion Ultra™ 2" Diagonals

2" Prism Diagonal Absolutely the finest-quality multi-coated 2" prism for highest light transmission.

For refractors #8770, **For Schmidt-Cassegrain** #8771
$219 (4.71)

2" Mirror Diagonal Affordable, high-quality first-surface optical flat star diagonal.

For Schmidt-Cassegrain #8772 **$109** (3.45)

Sky Wizard™

Electronic Finder & Sky Catalog

Let Sky Wizard do the work, while you relax and have fun observing!

- Find any celestial subject in 15 seconds!
- One minute set-up—no polar alignment or levelling.
- Observe hundreds of objects in just a few hours!
- For ANY telescope, with or without a motor drive. Even altazimuth or Dobsonian scopes!
- Digital display of celestial coordinates (RA and Dec).
- Built-in electronic sky catalog—find objects by their common catalog name, not their coordinates. Complete with object descriptions.
- Powered by a 9v battery or external 12v power supply (not included).

Sky Wizard Model 1
Database includes all 110 Messier.objects, 28 stars,
and the planets. Weighs just 4 oz.
#7801 **$179** (4.11)

Sky Wizard Model 2
Huge 2100+ object database, plus a user catalog to store 27 objects of your choice. Weighs just 6 oz.
#7802 **$249** (4.44)

Sky Wizard Model 3
Gigantic 10,000 object database, including entire NGC and IC and 837 interesting double and variable stars. Expanded object descriptions, RS-232 port.
#7803 **$349** (6.78)

Complete system requires Sky Wizard Model 1, 2, or 3, and a telescope installation package, sold separately.

Installation Packages

Includes two encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions. Installation packages are available for most telescope models. Call for details.

from $166

If You Take Your Computer With You . . .

NEW! Sky Wizard CTI

Computer–Telescope Interface

This handy, portable device connects the encod-ers on your telescope directly with your computer, allowing you to monitor your telescope's location with **TheSky** and **Deep Space** software programs (not included). Interface not needed with SkyWiz 3.
#7810 **$149** (4.11)

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If you are not completely satisfied with your purchase from the Orion Catalog, for any reason,

100% Satisfaction

just return it in new condition within 30 days after delivery for a prompt refund.

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- Shipping and handling charges for UPS Ground or US Mail to lower 48 United States are listed in parentheses after each price.
- Call for rates to Alaska, Hawaii, and Canada. We ship to U.S. and Canada only. Expedited delivery available; call for rates.
- Prices are subject to change or correction without notice.

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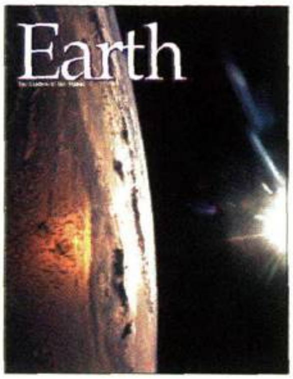

Looking at Earth

With its December issue, *Earth* is five years old. To celebrate we are offering a special collection of essays on the topic LOOKING AT EARTH, written by distinguished authors. They will discuss what people knew about Earth 1,000 years ago, what our great achievements in earth science have been since then and what critical questions remain.

Guest authors are . . .

- **Niles Eldredge,** paleontologist at the American Museum of Natural History
- **David Lindberg,** historian of science, University of Wisconsin -Madison
- **Eldridge Moores,** president of the Geological Society of America
- **Michael Wysession,** geophysicist at Washington University in St. Louis
- **Tom Wigley,** senior scientist at the National Center for Atmospheric Research
- **Daniel Orange** from the Monterey Bay Aquarium Research Institute

Earth

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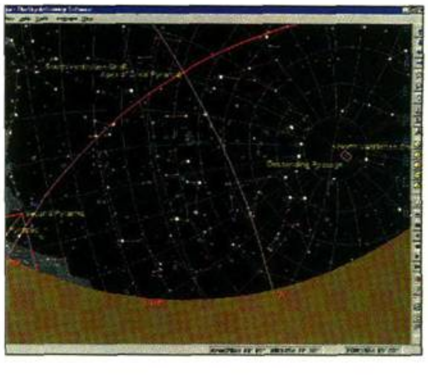
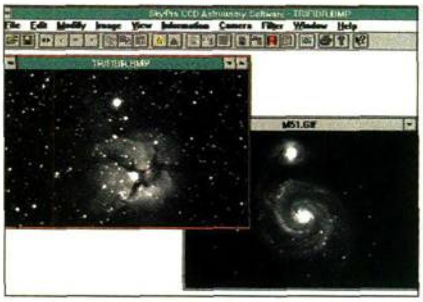
ASTRO BYTES



TheSky™ 4.0

TheSky™ Astronomy Software, a popular desktop planetarium program for more than 12 years, is now available as a Windows 95 Logo-compliant, true 32-bit application. This new version utilizes the newest technology and improves upon nearly every feature found in previous versions. It also allows for user customization. New features include object isophotes (including the Milky Way), POSS CD-ROM support, editable object symbols, additional object catalogs, database manager, and more. *TheSky*™ is available with three database "level" options — from 55,000 to 19 million objects — starting at $129. All levels include a CD-ROM; the entry level also includes 1.44MB floppy diskettes.

Software Bisque, 912 Twelfth Street, Golden, CO 80401, (303) 278-4478, fax (303) 278-0045, e-mail smb@bisque.com, http://www.bisque.com/thesky. Price: $249. Minimum recommended requirements: 80486 66MHz computer, 16MB RAM, 4X CD-ROM drive, mouse, and SVGA display (Version 4.0). Windows 95 or NT recommended, but not required.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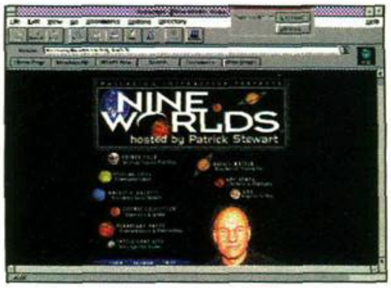
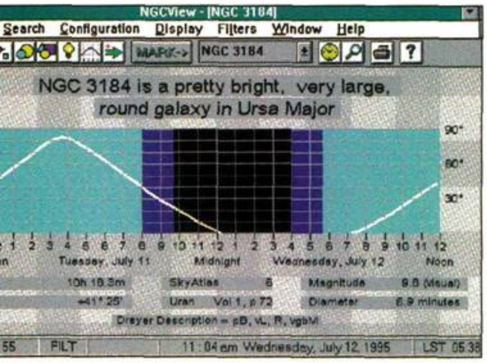
Software Bisque, 912 Twelfth Street, Golden, CO 80401, (303) 278-4478, fax (303) 278-0045, e-mail smb@bisque.com, http://www.bisque.com/thesky. Price: $199. Minimum requirements: 80386 33MHz computer with Windows 3.1 or later, mouse, and VGA display.

Nine Worlds™

Patrick Stewart narrates *Nine Worlds,*™ a CD-ROM which offers extensive information about the history and science of the nine planets in our solar system using a combination of narrations, visuals, and audio, along with current astronomical and scientific facts. It also allows online access to its proprietary Web site for up to date information, while connecting space enthusiasts around the world.



Palladium Interactive, 743 E. Franklin Street, Suite B, Spencer, IN 47460, (818) 829-1007, fax (812) 829-1020, e-mail 76702.407@compuserve.com, http://www.palladiumnet.com. Price: $39.95. Minimum recommended requirements: Windows 3.1, 80486-66MHz computer, 8 MB RAM, 2X CD-ROM drive, mouse, and an SVGA display. Macintosh: System 7.0.1 or higher, 68040/25 MHz, 8 MB RAM, 2X CD-ROM drive. Optional: Modem: 14.4k bps or greater recommended)



NGC 3184 is a pretty bright, very large, round galaxy in Ursa Major

10h 18.3m
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SkyAtlas 6
Uran Vol 1, p 72
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Diameter 6.9 minutes
Dreyer Description = pB, vL, R, vgbM

55 | FILT | 11:04 am Wednesday, July 12, 1995 | LST 05:38

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The search is further refined by adding object type, constellation, and elevation. Results of the search may be compiled on a log that can interface with *NGCView* and manage CCD image files.

Rainman Software, 100 Shale Place, Charlottesville, VA 22902-6402, (804) 984-2808, fax (804) 984-1241, e-mail rainman@rainman-soft.com, http://www.rainman-soft.com. Price: $39.95. Minimum requirements: 80386-based IBM PC/AT compatible computer, Windows 3.1, Windows for Workgroups, or Windows 95, mouse, and a VGA display.

Product information is as provided by the developer. Software developers may send new programs and upgrades to AstroBytes, ASTRONOMY Magazine, P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out ASTRONOMY's home page at **http://www.kalmbach.com/astro/astronomy.html**

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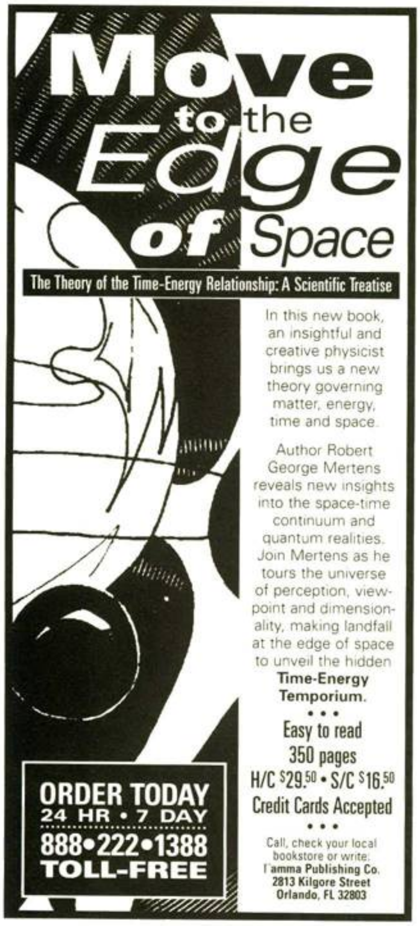
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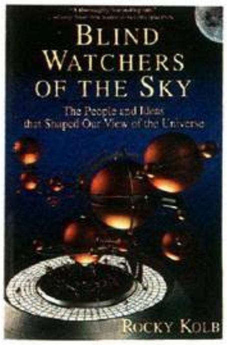
Blind Watchers of the Sky
Rocky Kolb (Helix Books, Addison-Wesley Publishing Co., 1996), ISBN 0-201-48992-9, 338 pages, hardcover, $25.00.


BLIND WATCHERS OF THE SKY
The People and Ideas that Shaped Our View of the Universe
ROCKY KOLB

Cosmologist Rocky Kolb has written a witty, and fascinating tour of the history of astronomy and cosmology. He introduces readers to those great scientists whose ideas wiped clean the astronomical slate: Tycho, Copernicus, Kepler, Galileo, Newton, Herschel, Einstein, Hubble, and others. Kolb describes their personalities and the interplay with their rivals, assesses their contributions to the body of astronomical knowledge, and points out the limits of their understanding.

Each of these brilliant thinkers, Kolb reminds us, moved science forward, yet remained bound by the limits of his own vision. Tycho's rant against his critics ("Oh thick wits. Oh blind watchers of the sky.") provides not only the book's title, but also its unifying theme. Kolb writes, "Although today we look harder and farther than we have ever looked, with all the instruments of modern science, and with all of the imagination and courage we can muster, we are still blind watchers of the sky."

For example, Tycho Brahe's observation of a supernova shattered the notion that the sky was immutable, yet he adhered to an Earth-centered model of the universe. More recently, Einstein's general theory of relativity opened the door for the big bang theory, but he clung to a static-universe model. And so on.

This book is graced with relevant anecdotes drawn from art, music, philosophy, history, and the author's personal experience. It is also laced with Kolbian wit, which usually works. For instance:

"Kepler's description of the journey that led him to discover that the orbit of Mars is an ellipse unfolds like a classic Alfred Hitchcock suspense thriller, where we know what the danger is, we see what is waiting around the next turn, but the unsuspecting hero doesn't. We want to scream out a warning (Don't open that door!) but we know the character on the screen can't hear us. So it is for a modern reader as the saga in [Kepler's] *New Astronomy* unfolds. We know the answer (It's an ellipse!) but Kepler doesn't. After a year of painstaking work, he concluded that the orbit [of Mars] is some sort of oval. (It's an ellipse!) But what sort of oval?..."

Kolb strives to make his book readable by eschewing mathematical formulae. He relegates a few formulae to a technically oriented final chapter. Kolb provides a lengthy bibliography with his personal assessment of the value of many books for readers with various interests and levels of expertise. His insights into the strengths of other authors may itself be worth the price of his book.

Kolb is a man of stature in the field of cosmology. As I read his repeated chronicling of the limits of vision of his "blind watcher" predecessors, I wondered if he would acknowledge the possibility that he and his colleagues are missing something obvious, and hugely significant. Not quite. He hints that the unresolved nature of "dark matter" perplexes today's astronomers and cosmologists. Yet he remains convinced, as did so many "blind watchers" before him, that the model of the universe with which he works is basically correct, although there are gaps that need to be filled in. One can only wonder if he's right. ☐

Lew Phelps (l_phelps@interramp. com) is a Pasadena, California, based writer, public relations consultant, and backyard astronomer.

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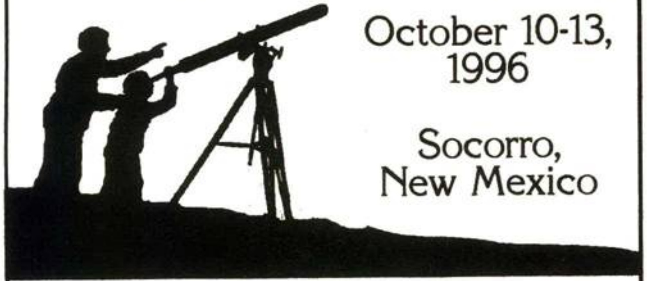

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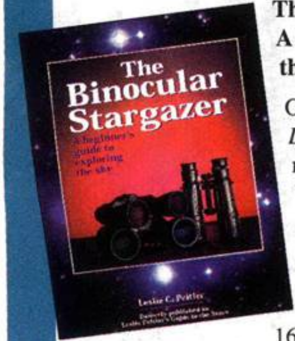

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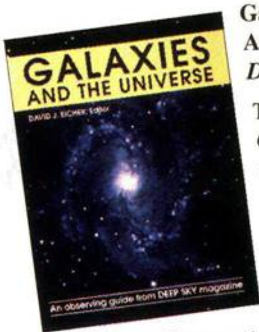

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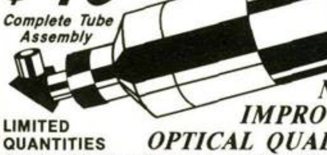

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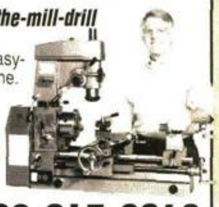

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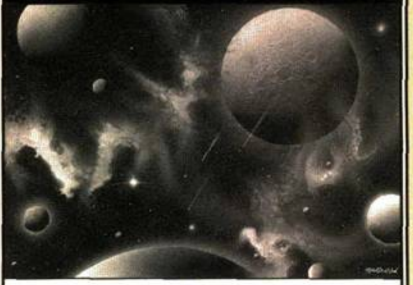

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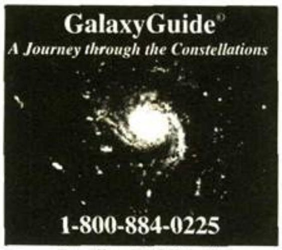
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AstroAssembly 1996, Seagrave Memorial Observatory, North Scituate, Rhode Island. Sponsored by Skyscrapers, Inc. Astronomical Society of Rhode Island. Contact: Conrad Cardano, 68 Colvintown Road, Coventry, RI 02816; (401) 828-0702.

October 8-13
Okie/Tex Star Party, Lake Murray State Park near Ardmore, Oklahoma. Sponsored by the Oklahoma City Astronomy Club. Contact Kyle Carr, (405) 483-5237, kcarr@icon.net, http://www.icon.net/~seadkins/okcac.

October 10-13
14th Annual Deep South Regional Stargaze, Percy Quin State Park near McComb, Mississippi. Sponsored by the Pontchartrain Astronomy Society of New Orleans, Louisiana. Contact Barry Simon, 820 Emerald Street, New Orleans, LA 70124, (504) 283-7592, astrox@ix.net com.com.

October 10-13
Enchanted Skies Star Party, Socorro, New Mexico. Contact the Socorro County Chamber of Commerce, (505) 835-0424, or Enchanted Skies Star Party, Box 743, Socorro, NM 87801.

October 11-12
Imaging the Sky '96, Salem, Oregon. Sponsored by the Friends of Pine Mountain Observatory. Contact Jim Girard, (503) 643-1813, http://pmo-sun.nero.net/~pmo/its.html.

October 11-12
Astronomy Festival, Kopernik Space Education Center, Vestal, New York. Sponsored by the Kopernik Astronomical Society. Contact the Society at the Kopernik Space Education Center, Underwood Road, Vestal, NY 13850, (607) 748-3685, or Roberson Center for the Arts and Sciences, 30 Front Street, Binghamton, NY 13905, (607) 772-0660.

October 11-12
7th Annual Twin Lakes Star Party, Golden Pond Observatory, Land Between the Lakes, Golden Pond, Kentucky. Sponsored by the West Kentucky Amateur Astronomers. Contact Jim Boren, 262 Shane Lee Circle, Dover, TN 37058, (615) 232-6820.

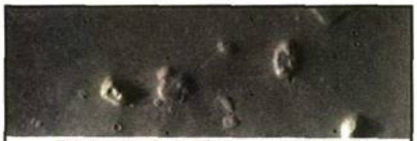
October 11-13
Eastern Iowa Star Party, Wapsi River Environmental Center, Dixon, Iowa. Sponsored by the Quad Cities Astronomical Society. Contact William R. Myers, (319) 359-4286, qcas@corvus.com.

October 11-13
Stella-Della-Valley Amateur Astronomers' Convention, Camp Onas, Ottsville, Pennsylvania. Sponsored by the Bucks-Mont Astronomical Association. Contact Ed Melnick, 1443 Devon Rd., Warminster, PA 18974, (215) 443-7929.

October 19-20
European Satellite Observers Meeting, Eurosom 2, Hotel Ibis, Ghent, Belgium. Registration deadline September 25. Contact Bart De Pontieu, Max-Planck-Institut für Extraterrestrische Physik, D-85740 Garching-bei-Muenchen, Germany, bdp@mpe-garching.mpg.de.

October 25-27
12th Annual Midwest Space Development Conference, Strongsville Holiday Inn, Rts. 71 and 82, Strongsville, Ohio. Sponsored by the National Space Society, Cuyahoga Valley Space Society, and EXITUS, Inc. Contact MSDC, 6167 Oakwood Cir., North Ridgeville, OH 44039, (216) 826-0330. ☐

Please submit club announcements four months in advance to Meetings and Events, ASTRONOMY, *P.O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com.*


This is a small clip of a much larger image showing the whole artifact field.

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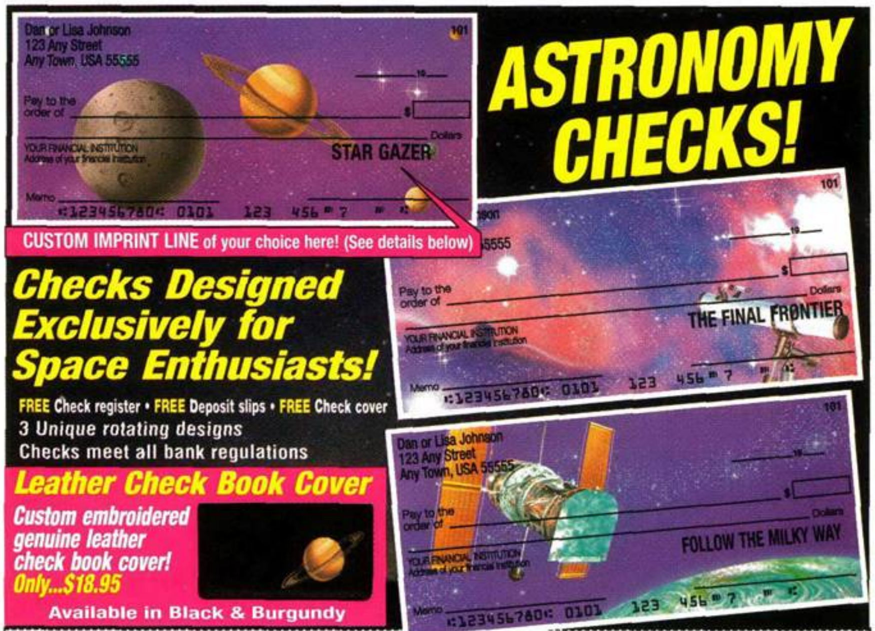
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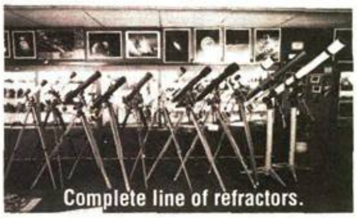
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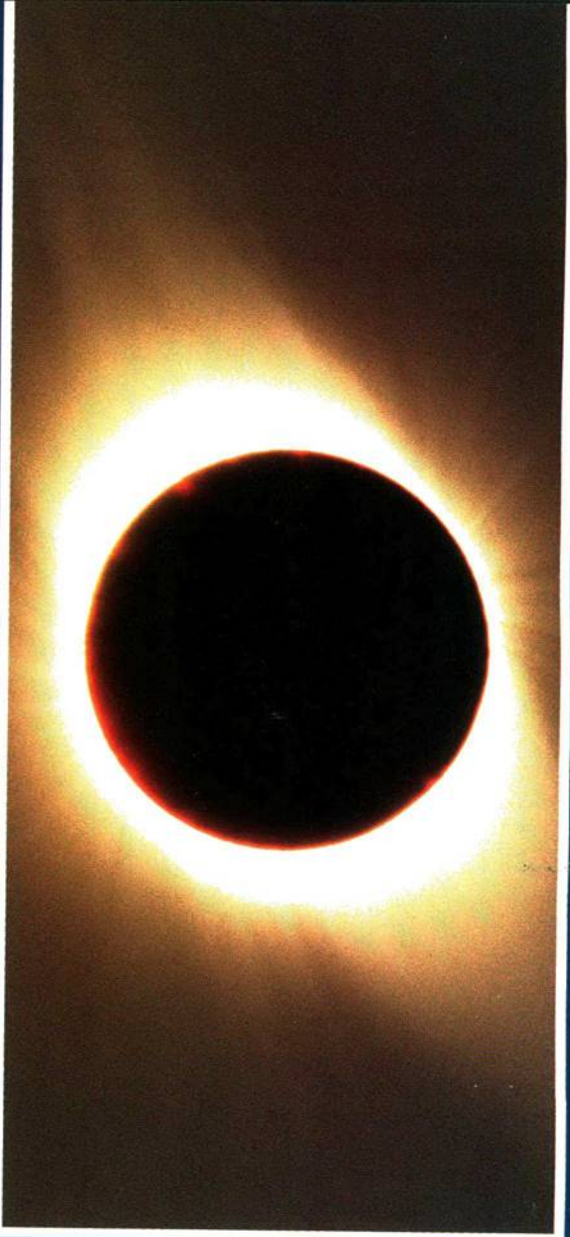

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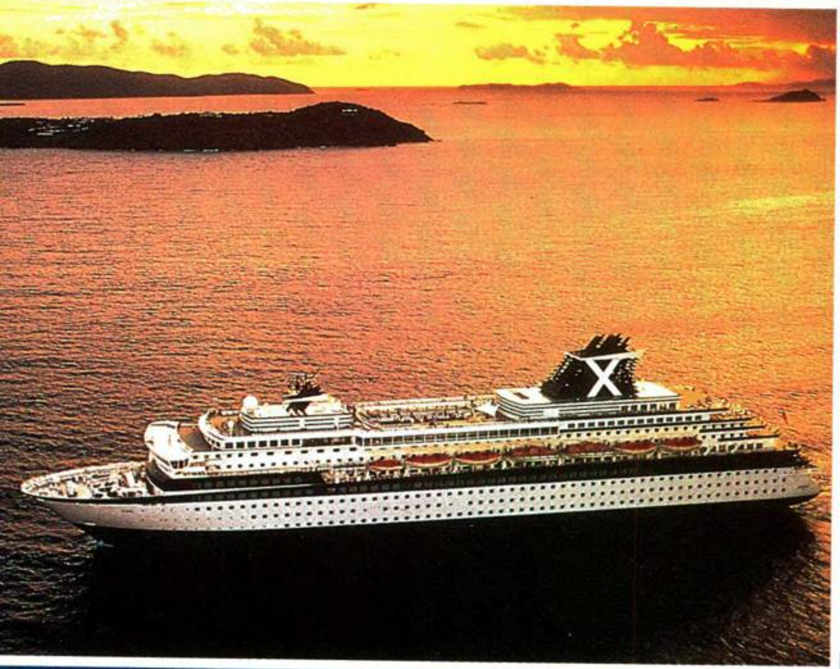

ASTRONOMY editors Dave Eicher and Rich Talcott invite you to daily talks and shipboard constellation watches. Then, on February 26, everyone will view the total solar eclipse through solar-safe filtered telescopes and binoculars. A trip you won't want to miss!

Watch ASTRONOMY Magazine for more details or call George Schy of A1 Tours at:

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ASTRONOMY

Eclipse photo taken by Ernest Piini.

Don't Forget the Galaxy Groups

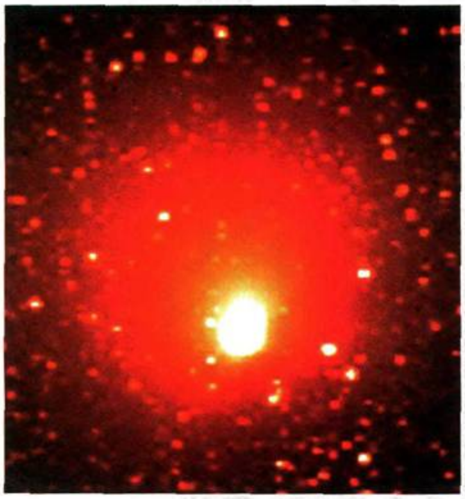
Brenda Culbertson of Harveyville, Kansas, reminds us not to forget the galaxy groups. Most observers — even armed with large Dobsonians — target relatively bright objects over and over. After viewing the Andromeda Galaxy many times over, we're ready to go beyond, suggests Culbertson.

"A good galaxy group is a poor cluster with at least four galaxies of 15th magnitude or brighter," she says. In Andromeda, try the NGC 48 Galaxy Group (0h14.0m, 48°14'). The brightest member, NGC 48, is a barred spiral galaxy glowing faintly at blue magnitude 14.7. It measures 1.7' by 1.1' and lies some 88 million light-years away. North of the object are the even fainter galaxies IC 1534, IC 1535, and IC 1536. NGC 49 and NGC 51 are also members.

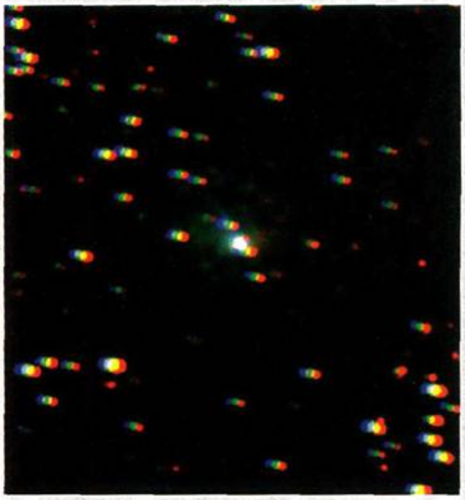
Also in Andromeda is the NGC 68 Galaxy Group (0h18.3m, 30°04'), the brightest galaxy of which, NGC 68, glows at magnitude 13.0. It's a lenticular galaxy measuring 1.8' by 1.5' and lying 300 million light-years distant. At least eight galaxies are clustered within this group: NGC 67, NGC 68, NGC 69, NGC 70, NGC 71, NGC 72, NGC 74, and an anonymous galaxy.

Finally, try the NGC 80 Galaxy Group (0h21.2m, 22°21'), also in Andromeda. NGC 80 itself is a 12th magnitude lenticular galaxy

Comet Hale-Bopp
Jack Newton
(25-inch f/5 reflector, Pictor 1616 CCD camera, composite of 2-minute red, 4-minute green, and 6-minute blue exposures taken July 7, 1996)



Hale-Bopp's Inner Coma
Tim Puckett
(12-inch reflector at f/8, ST-6 CCD camera, taken July 11, 1996)



Comet Kopff
Joe Peck
(12-inch SCT at f/6, ST-6 CCD camera, composite of ten 30-second exposures taken April 18, 1996)

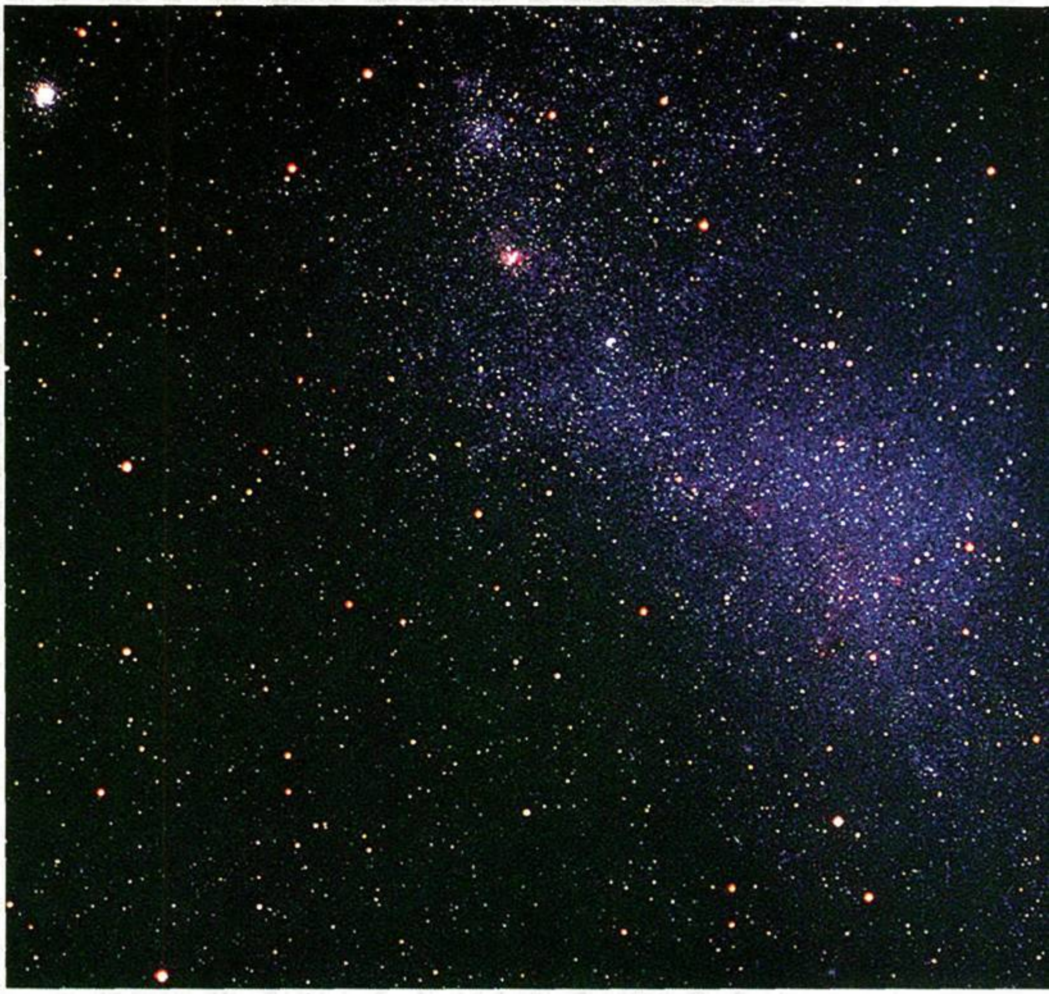
measuring 2.5' by 2.3' and some 250 million light-years distant. This little assemblage holds NGC 79, NGC 82/83, NGC 85A, NGC 85B, NGC 86, NGC 93, NGC 96, IC 1542, and an anonymous galaxy.

Stardate South Island 1996. Readers Tim Homes and Rose McDermott reported on one of New Zealand's astronomical gatherings, Stardate South Island, which occurred February 23–25, 1996, at Staveley. "This was my fourth, and the best yet," says Homes. "Telescopes large and small probed the delights of the Large and Small Magellanic Clouds, the Jewel Box, Omega Centauri, Eta Carinae, and other treats of the southern sky.

"The breeze was cold, but failed to deter anyone from viewing," he continues. Comet Hyakutake as well as a bevy of globulars, planetaries, and galaxies highlighted the observing, according to Homes.

Flash Green with Caution. "Having read about the 'green flash,' I think claims far outnumber the sightings," says Judith Barak of North Potomac, Maryland. She reports seeing it once but not again after much time spent on shipboard. "Such sightings indeed happen, especially at sea, but I think they're pretty rare," she says. □

ASTRONOMY wants to share your observations of the sky with our readers. Send reports, sketches, photographs, and disks to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187–1612. Please label each photo with photo data, name, address, and social security number. You may send written reports and images via the Internet to: rreports@astronomy.com

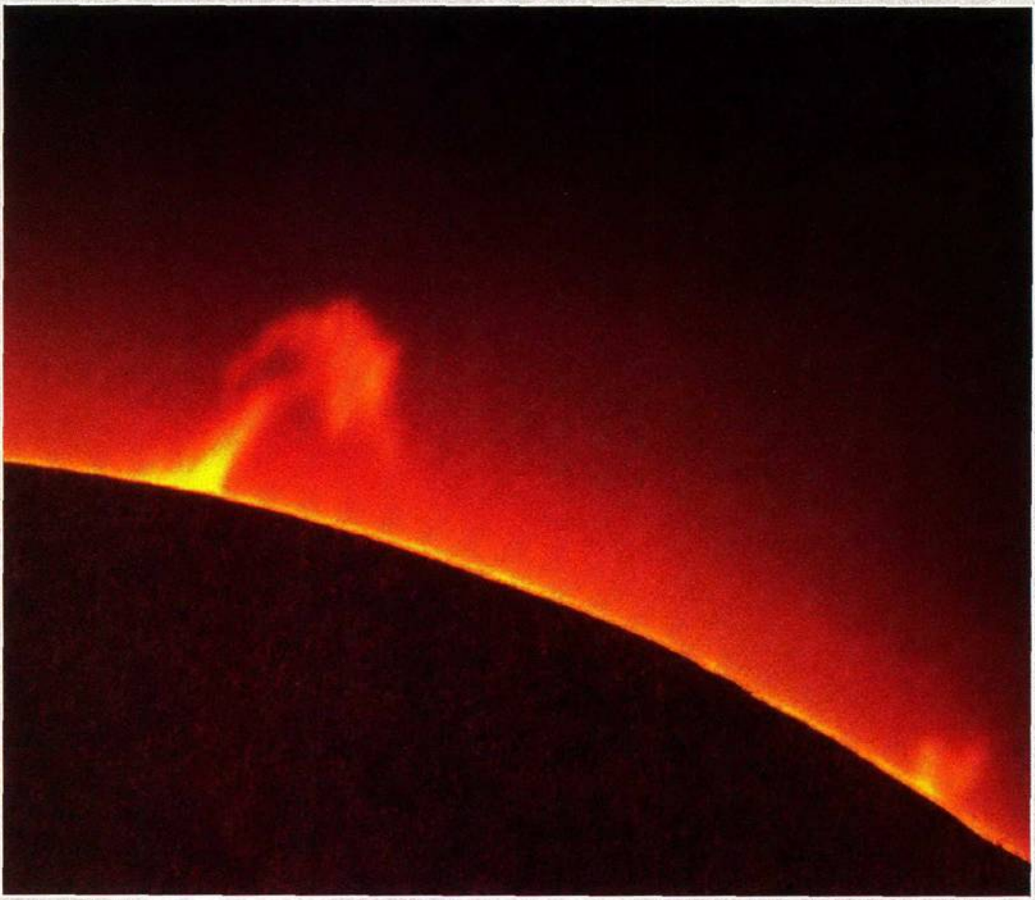


The Small Magellanic Cloud and Cluster 47 Tucanae
Bob Sandness
(8-inch f/1.5 Schmidt camera, Fuji G800 film, 15-minute exposure)

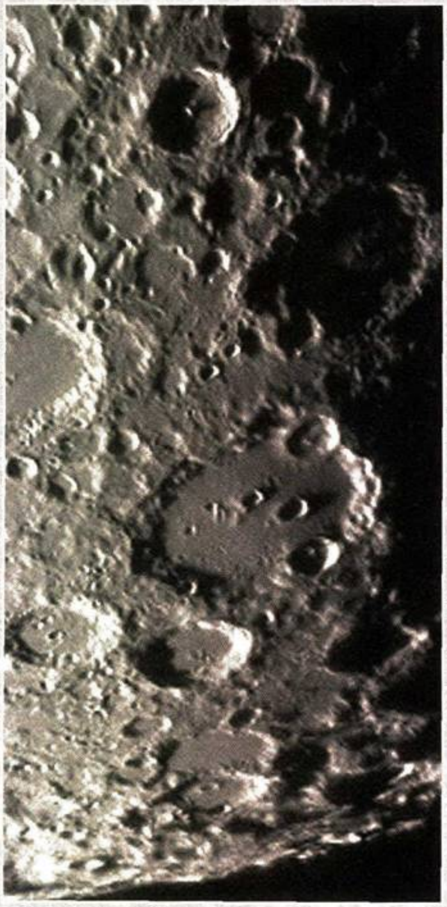
Full Moon
Sheldon Reynolds
(10-inch SCT at f/6, Fuji Provia 400 film)

The Lunar Eclipse of
Pierre Guillermier
(7-inch f/7 Cassegrain, F

996

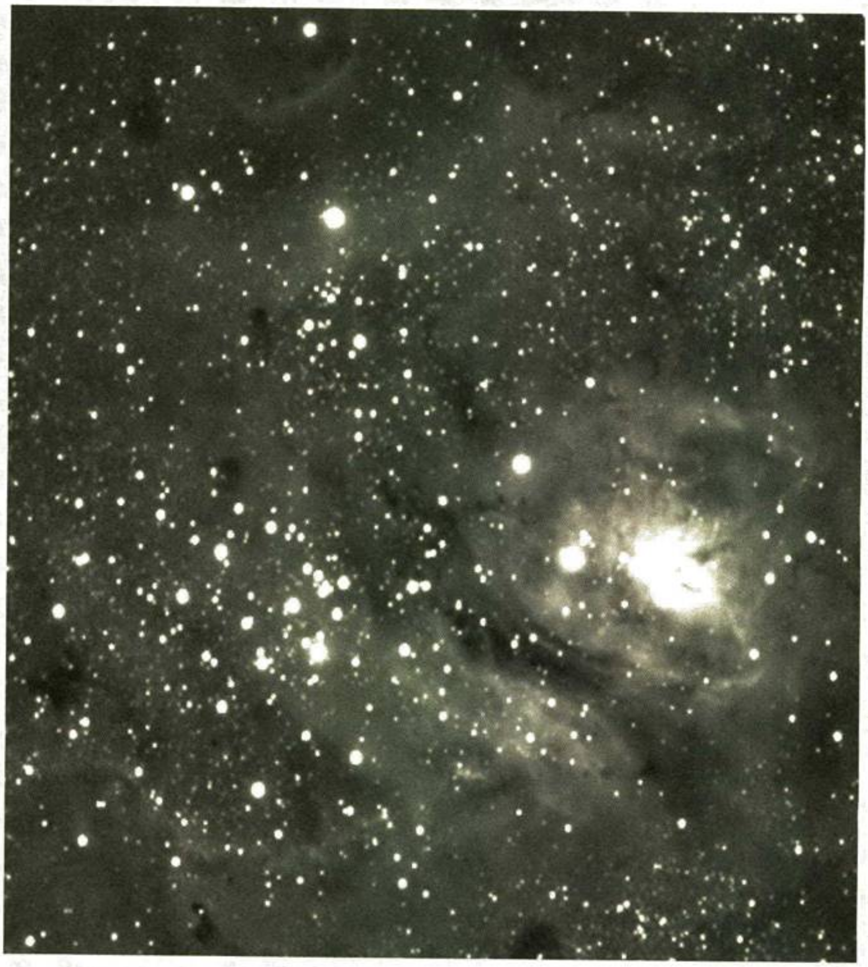


A Towering Solar Prominence
H. J. P. Arnold
(7-inch f/9 refractor, Tech Pan film, Hα filter, taken June 6, 1996)



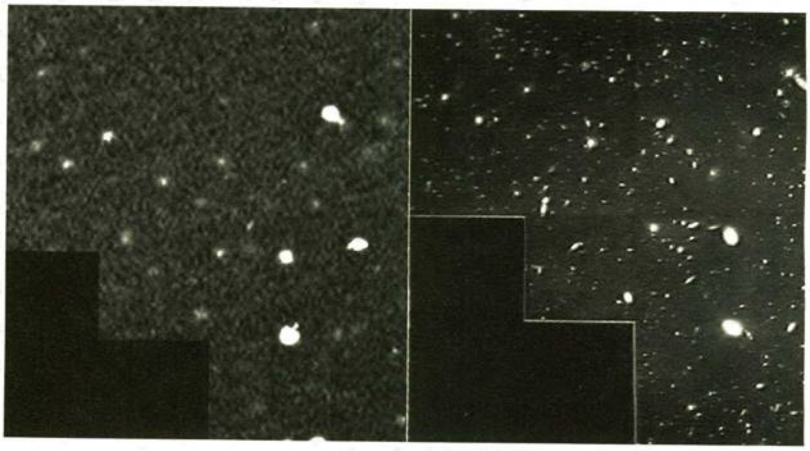
The Clavius Region
Eric Roel
(10-inch f/12 SCT, Starlight Xpress CCD camera)

Galaxies NGC 5905 and NGC 5908 in Draco
Preston Scott Justis
(10-inch f/6 reflector, hypered Tech Pan film, 120-minute exposure)

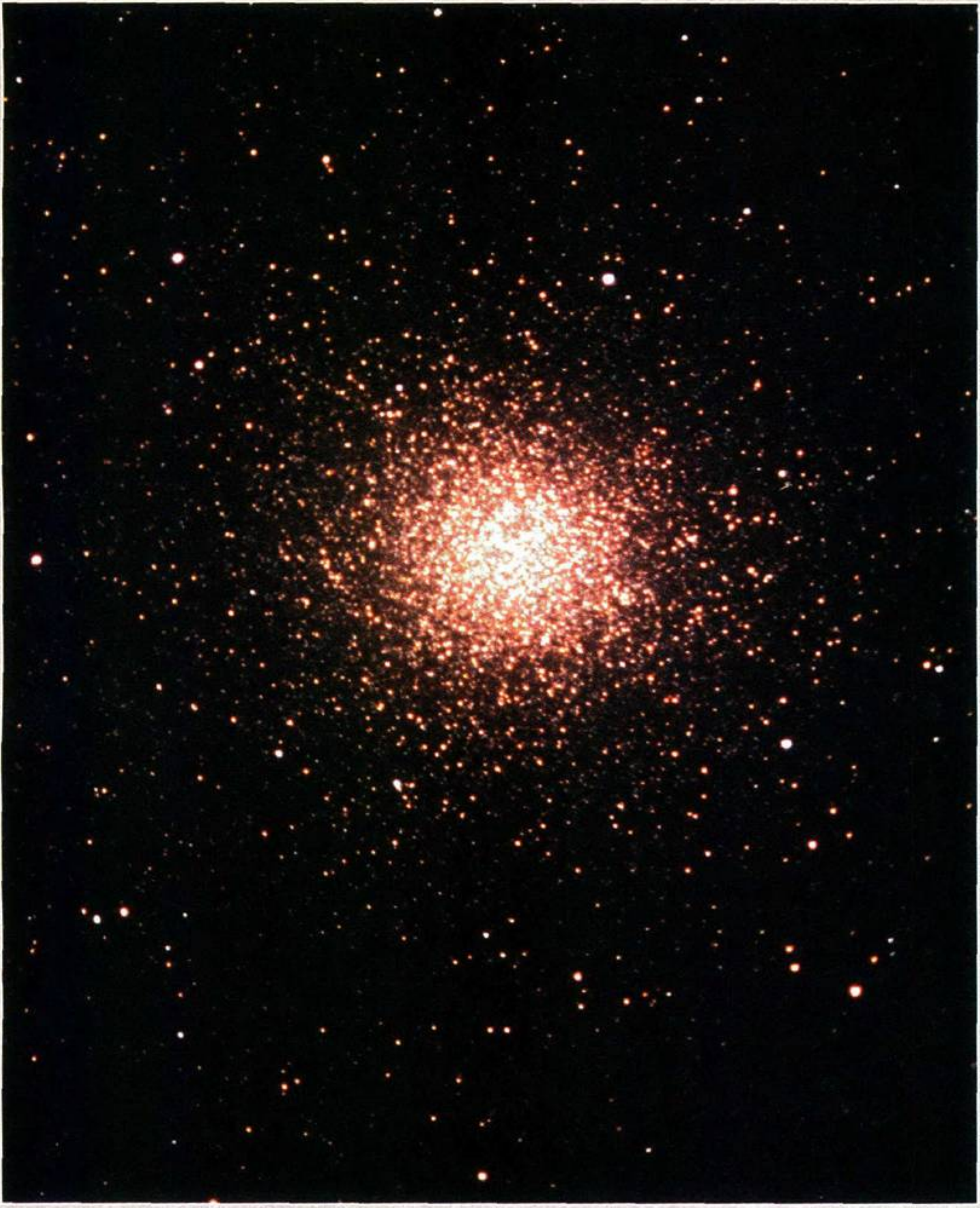


The Lagoon Nebula (M8)
David Hanon
(7-inch refractor at f/5.5, ST-8 CCD camera, composite of two 5-minute exposures)

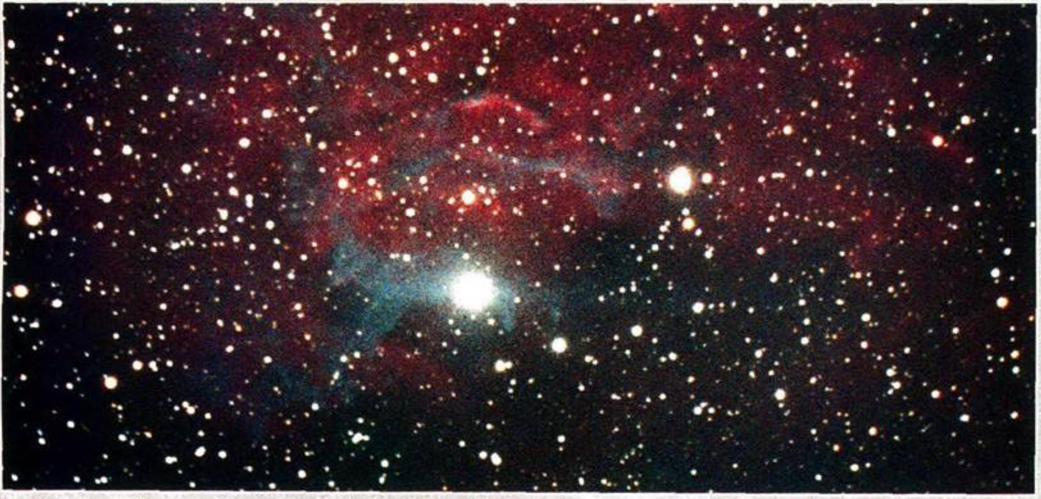
Edge-on Spiral NGC 891 in Andromeda
Tim Hunter and James McGaha
(24-inch f/5 reflector, HPC-1 CCD camera, composite of 1-minute red, 2-minute green, and 3-minute blue exposures)



The Hubble Deep Field
Jack Newton and NASA
(The right-hand image shows the deep field imaged with the Hubble Space Telescope; the lefthand image shows the same field imaged with a 25-inch f/5 reflector and a Pictor 1616 CCD camera)



Globular Cluster Omega Centauri
Eduardo Pulver
(8-inch SCT at f/6, Fuji Super HG 400 film)



Emission Nebula IC 405 in Auriga
Ken Blankenship and Dennis Batis
(14-inch SCT at f/5, Fuji Super HG 400 film, 150-minute exposure)

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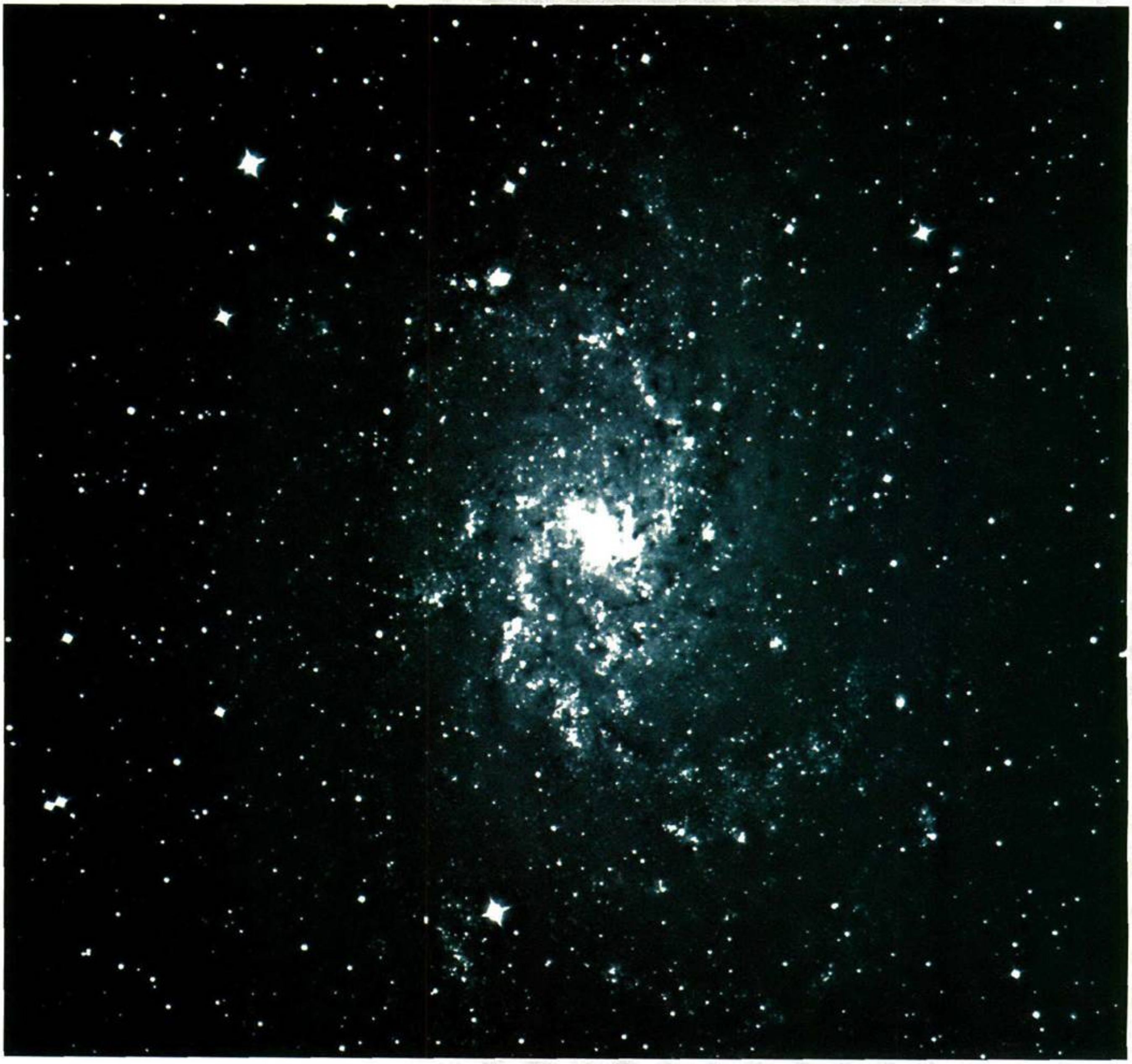

The Pinwheel Galaxy (M33)

Chris Schur
(12.5-inch f/5 reflector, hypered Tech Pan film)

Although the Andromeda Galaxy (M31) is usually touted as the most distant object visible to unaided eyes, its neighbor galaxy M33 in Triangulum actually holds that distinction for eagle-eyed observers. The soft glow of M33, sometimes called the Pinwheel, has a total magnitude of 5.7. Thus, if compressed into a point, the galaxy would shine slightly brighter than a 6th-magnitude star. This galaxy lies 3.6 million light-years away, 40 percent farther than M31.

Chris Schur's razor-sharp portrait of M33 on Tech Pan film reveals the network of star-forming regions in the galaxy's spiral arms. The giant emission nebula NGC 604 lies in the upper left region of the galaxy's arms.

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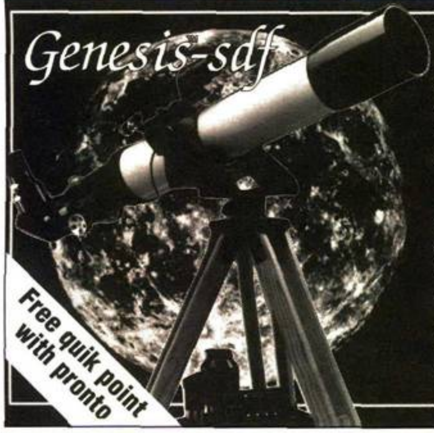

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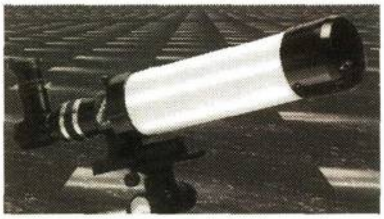

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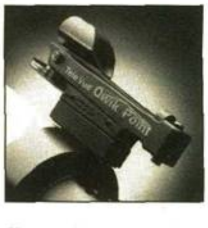

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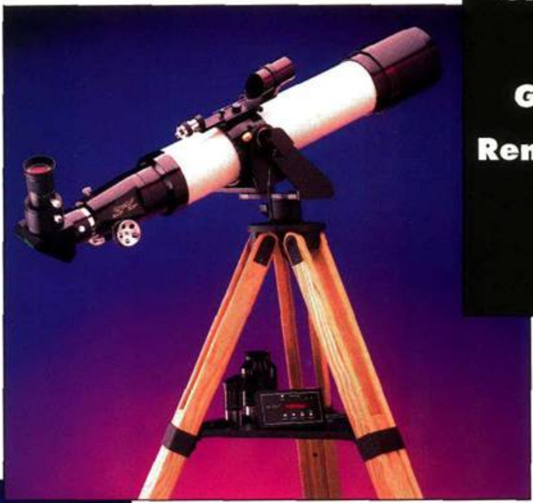
Tele Vue Optics, Dept A, 100 Route 59, Suffern, NY 10901. (914) 357-9522.

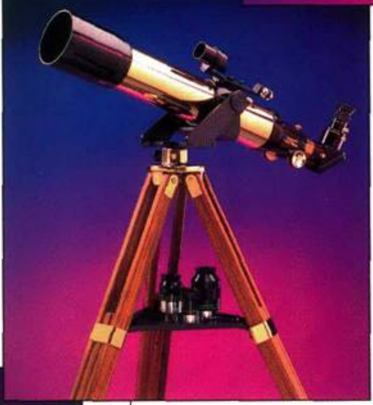
TELE VUE REFRACTORS

Unforgettable images…both rich-field & diffraction limited…pride of owning a fine piece of American craftsmanship…convenience; These unsolicited sentiments plus those below have been expressed by so many Tele Vue telescope owners. Our goal is to produce scopes rich in value, so you may enjoy exploring all facets of your universe. Call your dealer today and begin an unforgettable journey.

Unforgettable Images.
Genesis-SDF
Renaissance-SDF
Pronto
Ranger



SDF - 101mm Ap., f/5.4 APO
Pronto - 70mm Ap., f/6.8 E.D.
Ranger - 70mm Ap., f/6.8 E.D.



GENESIS/RENAISSANCE-sdf

"…On critical star tests, the Genesis-sdf performed flawlessly…The level of color correction in the SDF was impressive. The edge of the Moon was pure white. Saturn appeared without any trace of a blue halo. This is a superb level of color correction in any refractor, let alone one this fast and portable… Combined with premium wide-angle eyepieces, this is a telescope capable of providing stunning low-power views of Milky Way starfields. And yet under good seeing conditions, the sharp optics will easily handle 200 to 250 power." — Astronomy

I'm amazed at the views! Workmanship excellent - my 8" SCT will gather dust!! R.L. - NH

Wanted high performance APO-Fluorite refractor for wide field views with ultra sharp stars. A fantastic little refractor telescope that I enjoy using more than any other telescope I've ever owned Thank you. JB. - Australia

Probably slightly better than Zeiss APQ, and the one with largest aperture that can be moved by one person only. It's really marvellous. W.D. - Germany

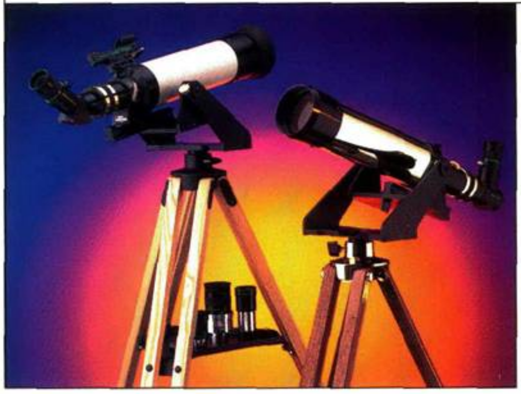
PRONTO

What a great little scope! I found M97, M108, NGC4361, NGC2997& NGC2438 — all from the suburbs. Open clusters look better in my Pronto than in any scope I've ever used. A.E. — AZ

Wow! Perfection in design & quality. Images I only dreamed of. Given a choice of reflectors twice the size, I'll take Pronto. L.R. — CO

The ultimate "shoot & scoot" scope! M.L. — Ont.

Tired of heavy, computerized, SCTs & spending time with them rather than stars. Superb!! Flawless design & performance. What a joy to use. Thanx Al. M.F. — NY



Good sharp view of the Moon & comet Hyakutake. The S&T review persuaded me that going for quality would be good. R.F. - MO

RANGER

" We put Tele Vue's new 70mm f/6.8 refractor through its paces and discovered an ideal travel telescope for astronomy, wildlife, or sports… Saturn's moon Titan as a pinpoint, and a clear edged planetary disc of pale beige yellow with hazy equatorial banding…the tiny, elaborate trapezium of M29 stood out clearly…the companions of Andromeda, M32 and NGC205 showed clearly…the northern component of the Double-Double showed plenty of black space" — Sky & Telescope

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CELESTAR 8 *by* Celestron®

THE LOWEST PRICE EVER ON AN 8" CELESTRON FORK-MOUNTED SCHMIDT-CASSEGRAIN TELESCOPE

- An economical but full featured 8" Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8 to offer the lowest price **ever** on a **Celestron** fork mounted 8" with so many features.
- No sacrifice was made in the optics as the superior quality **Celestron** hand-figured system with Starbright® coatings is standard.
- The electronics are DC and the same as supplied with the C5$^+$ telescope.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the *Sky & Telescope* review – "the digital electronics of the C5$^+$ delivered a near-perfect sidereal tracking rate."
- The Celestar 8 is powered by a single 9-volt alkaline battery and runs for 50 hours! The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0 to 90°.
- The new and unique Wedgpod is a combination tripod and wedge. It has a fixed height (33") and is lightweight without compromising its stability.
- **Made in the U.S.A.**
- Standard accessories included are: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).

Celestar 8 with optional hand control

CELESTRON
OFF ON
DIM
MODE
ENTER
UP
DOWN
Advanced Astro Master

The **Celestar 8 Computerized** telescope is the same as the Celestar 8 but with the addition of a factory **installed** and **tested** Advanced Astro Master®.

This pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery.

Contains an RS-232 serial interface to enable usage from PC programs.

CELESTRON FORK MOUNTED SCHMIDT-CASSEGRAIN TELESCOPES

C5 – the ultimate in portability in a Schmidt-Cassegrain. 5" f/10 hand figured, diffraction limited optics with Starbright® coatings. Spoken highly of in reviews by *Astromony* and *Sky & Telescope*. The C5 is an AC model. The **C5$^+$** is a DC model for astronomy on the go and it runs off a single 9-volt alkaline battery. The C5$^+$ also comes with a built-in drive controller. Included standard are the equatorial wedge, 5 x 24 Finderscope, Star Diagonal – 1¼ and a 25mm SMA eyepiece – 1¼".

ULTIMA® 9¼ – 2350mm f/10 with Starbright® coatings. A new, large aperture size utilizing the renowned Ultima PEC drive – totally cordless DC servo quartz drive system with PEC and powered by a single 9-volt alkaline battery. A unique focusing micrometer for ultra precise focusing for CCD imaging or astrophotography is included. Standard accessories are wedge, tripod, 6x30 Finderscope, hand control, 25mm SMA eyepiece – 1¼".

ULTIMA® 11 – 2800mm f/10 with Starbright® coatings. The largest Ultima (11") has been redesigned with more rigid sand castings for additional stability. Utilizes the same drive base as the Ultima 9¼ of which *Sky & Telescope* said, "Ultima's drive error was the least I have ever seen in a mass-market telescope". Standard accessories include a wedge, tripod, 7x50 Finderscope, hand control, 26mm Plössl eyepiece – 1¼".

CELESTRON®

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

Celestron International • 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835